MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXXIV. FEBRUARY 13, 1914. NO. 4

ANNUAL GENERAL MEETING.

Major E. H. HILLS, C.M.G., D.Sc., F.R.S., PRESIDENT, in the Chair.

The President announced the loss the Society had sustained by the death of Sir David Gill, and read the resolution of the Council (p. 259).

The Report of the Auditors of the Treasurer's accounts for the year 1913 was read, and is given on p. 264.

The Annual Report of the Council was partly read; see pp. 260 to 371.

The Address was delivered by the President, who gave an account of the grounds on which the Gold Medal had been awarded to Professor Max Wolf, for his work in Celestial Photography and Spectroscopy. The Medal was then handed to Professor Wolf.

Professor Max Wolf exhibited and described a series of slides illustrating his work on nebulæ and their spectra.

The President having appointed the Scrutineers, the Society proceeded to the ballot for Officers and Council for the ensuing year. The names of those elected are given on p. 390.

The thanks of the Meeting were given to the retiring Vice-Presidents and Members of Council, and also to the Auditors of the Treasurer's accounts and to the Scrutineers of the ballot.

Richard Henry Bulkeley, J.P., Wallerawang, New South Wales, Australia;
Richard Thomas Cullen, Royal Observatory, Greenwich, S.E.;
R. Jarry-Desloges, Director of the Observatory, Sétif, Algeria;
Robert John Pocock, B.A., B.Sc., Director of the Nizamiah Observatory, Hyderabad, Deccan, India;
William Thow, M.Inst.C.E., Inglewood, Warrawee, New South Wales, Australia;
Lloyd A. H. Warren, M.A., Ph.D., Assistant Professor of Mathematics and Astronomy in the University of Manitoba, Winnipeg, Canada; and
William Moody Witchell, Royal Observatory, Greenwich, and 36 Sandbourne Road, Brockley, S.E.,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Henry Frederick Baker, Sc.D., F.R.S., Lowndean Professor of Astronomy and Geometry, University, Cambridge (proposed by H. F. Newall);
Rev. Walter Bidlake, M.A., The Vicarage, Crewe (proposed by W. E. Plummer);
Thomas Lydwell Eckersley, B.A., B.Sc., Khedivial Observatory, Helwân, Egypt (proposed by B. F. E. Keeling);
Capt. William G. Walker Gilchrist, Ingleneuck, Swaythling Lawn, Southampton (proposed by M. H. Clarke);
Ivor Blashka Hart, B.Sc., 9 Clapham Terrace, Leamington, Warwickshire (proposed by E. S. Phillips);
Hugh Walsham, M.D., M.A., F.R.C.P., 114 Harley Street, W. (proposed by J. W. Gifford); and
Charles Seymour Wright, M.A., F.R.G.S., Gonville and Caius College, Cambridge (proposed by F. J. M. Stratton).

The Council desire to record their sense of the great loss which the Society itself and science in general have sustained by the death of Sir David Gill.

As Fellow of the Society since 1867, as President in 1909–1911, and as Foreign Secretary from 1911 to the date of his death, his services have always, more especially since his return from the Cape, been freely placed at the disposal of the Society.

It is, however, on the higher ground of his lifelong activity in astronomical research, of his able and efficient administration of the Royal Observatory, Cape of Good Hope, and of his influence on the whole trend of astronomical thought and methods of observation during the past forty years, that he has the highest claim to the respect and admiration of all astronomers.

The Council, in requesting the President to convey their sympathy to Lady Gill on her bereavement, desire him to ask her to accept it not only as a token of their esteem for him as an astronomer, but also as, in some degree, an expression of their sorrow at the loss of a personal friend.

Report of the Council to the Ninety-fourth Annual General Meeting of the Society.

The following table shows the progress and present state of the Society :—

	Patron	Honorary Members	Fellows		Associates	Total
			Compounders	Annual Subscribers		
1912 December 31	1	1	249	472	48	771
Since elected	...	...	+2	+33	+3	...
Deceased	...	...	−10	−10	−3	...
Resigned	...	...	...	−9	...	...
Since compounded	...	...	+2	−2	...	...
Removed from list	...	...	...	−7	...	...
1913 December 31	1	1	243	477	48	770

TREASURER'S ACCOUNTS FOR 1913.

Mr. Knobel's Account as Treasurer of the Royal

RECEIVED.

	£ s. d.	£ s. d.
Balances, 1912 December 31 :—		
At Bankers', as per Pass-book	279 18 10	
Not credited till 1913	11 0	
In hand of Assistant Secretary on Account of Turnor and Horrox Fund	3 16 3	
In hand of Assistant Secretary on Petty Cash Account	10 8 8	
		294 14 9
Dividends :—		
£1,250 Metropolitan 3-per-cent. Stock ...	35 6 4	
£2,000 Swansea Corporation 3½-per-cent. Stock	65 18 4	
£3,500 East Indian Railway 3-per-cent. Debenture Stock	98 17 4	
£3,500 London and North-Western Railway 3-per-cent. Debenture Stock	98 17 6	
£4,000 Midland Railway 2½-per-cent. Debenture Stock	94 3 4	
£1,000 Lancashire and Yorkshire Railway 3-per-cent. Preference Stock	28 5 0	
£2,400 Gas Light and Coke Co. 3-per-cent. Debenture Stock	62 3 0	
£2,000 Commercial Gas Co. 3-per-cent. Debenture Stock	56 10 0	
		540 0 10
Received on account of Subscriptions :—		
Arrears	199 8 9	
Annual Contributions for 1913	749 14 0	
,, ,, in advance	6 6 0	
Admission Fees	77 14 0	
First Contributions	50 8 0	
		1,083 10 9
Composition Fees		74 11 0
Sales of Publications :—		
At Society's Rooms	19 2 0	
At Wesley & Son's 122 12 3		
Less discount, 10 per cent. 12 5 2		
	110 7 1	
Half share of proceeds of sale of Sir W. Herschel's Collected Scientific Papers, received from the Royal Society	73 7 0	
		202 16 1
Sales of Photographs		23 4 6
Income Tax refunded by Commissioners of Inland Revenue		33 2 2
		£2,252 0 1

Examined and found correct, January 5, 1914.

J. W. Capstick.
Richard Inwards.
H. P. Hollis.

Astronomical Society from January 1 to December 31, 1913.

PAID.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
,, ,, Editing Society's Publications	50	0	0			
,, ,, Special Grant	20	0	0			
Clerk: Salary	100	0	0			
				420	0	0
House Duty	2	12	6			
Fire and Servants' Insurance	10	8	9			
				13	1	3
Printing, etc.:—						
Monthly Notices	442	4	3			
List of Fellows and Miscellaneous	46	18	0			
Photo-engraving and Lithography	67	4	2			
Sir W. Herschel's Collected Papers: half share of cost of binding	4	7	6			
				560	13	11
Suspense Account: advanced for expense of reproduction of Franklin-Adams Charts ...				120	0	0
Cataloguing Astronomical Literature for the International Catalogue				30	0	0
Reproduction of Photographs for sale				27	13	10
Turnor and Horrox Fund, and Council Grant for purchase of Books for Library	22	3	9			
Binding for Library	22	19	1			
				45	2	10
Expenses of Meetings	20	8	0			
Lantern Attendance	3	10	0			
Time Signal: Rental of wire...	5	0	0			
Wiring for Ventilating fan; Meeting-Room ...	24	18	0			
				53	16	0
Subsn. to *Centralstelle für astronomische Telegramme*				1	5	1
Telephone Subscription	6	10	0			
Registration of Telegraphic Address	1	1	0			
Postage and Telegrams	91	13	10			
Carriage of Parcels	1	12	8			
Stationery and Office expenses	15	3	5			
				116	0	11
House expenses: Allowance and sundry expenses	54	13	5			
Coal, Gas, and Electric Light	64	7	2			
Sundry fittings and repairs	4	14	7			
Sundries	5	12	4			
				129	7	6
Portrait of Sir William Herschel				35	6	6
Expenses of Conversazione on July 15				15	15	2
Jackson-Gwilt Fund; Gift to Mr. Espin	30	0	0			
,, ,, ,, 5 medals, etc.	12	16	0			
				42	16	0
Lee and Janson Fund: Grants to Mrs. M'Dowell	9	0	0			
,, ,, ,, ,, Mrs. Henkel ...	7	0	0			
,, ,, ,, ,, Mrs. Smart ...	10	0	0			
				26	0	0
Purchase of £400 Gas Light and Coke Co. 3-per-cent. Debenture Stock				313	9	6
Cheque book and Bankers' charges on Cheques ...					13	1
Balances, 1913 December 31:—						
At Bankers', as per Pass-book	232	4	4			
Cheque not credited till 1914	2	2	0			
At Bankers', on Deposit	60	0	0			
In hand of Assistant Secretary on Account of Turnor and Horrox Fund	1	12	6			
In hand of Assist. Sec. on Petty Cash Account	4	19	8			
				300	18	6
				£2,252	0	1

Report of the Auditors.

We have examined the Treasurer's accounts of receipts and expenditure for the year 1913, and certified the same to be correct. The cash in hand on December 31, 1913, including the balance at the Bank, etc., amounted to £300 18*s.* 6*d.*

The funded property of the Society has been increased during the year by the purchase of £400 Gas Light and Coke 3 per cent. Debenture Stock. The sum of £60 has been placed on deposit at the Bank on behalf of the Lee and Janson Fund.

The books, instruments, and other effects in the possession of the Society have been examined, and they appear to be in a satisfactory condition.

A list has been laid on the table of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting of the Society, together with the amount against each Fellow's name.

(Signed) J. W. Capstick.
Richard Inwards.
H. P. Hollis.

1914 *January* 5.

Gifts to the General Funds of the Society.

In 1836 John Lee, Esq., LL.D., gave the Advowson of the living of Hartwell; in 1844 he gave the Advowson of the living of Stone, Bucks. In 1879 these Advowsons were repurchased by his heir, Edward Lee, Esq., for £700.

The Lawson Bequest (1856): Henry Lawson, Esq., bequeathed to the Society the sum of £200, free of legacy duty.

The Carrington Bequest (1876): R. C. Carrington, Esq., F.R.S., bequeathed to the Society £2,000 Consols. This was sold in 1899, and stands now in £1,881 14*s.* London and North-Western Railway 3-per-cent. Debenture Stock.

The Lambert Bequest (1877): C. J. Lambert, Esq., presented to the Society the sum of £500, free of legacy duty, being part of a sum of money bequeathed by his father, Charles Lambert, Esq., for scientific purposes.

The McClean Bequest (1905): Frank McClean, Esq., LL.D., F.R.S., bequeathed to the Society the sum of £2,000, free of legacy duty. This now stands in £1,871 1*s.* 6*d.* Swansea Corporation 3½-per-cent. Stock.

The Farrar Bequest (1906): The Rev. A. S. Farrar, D.D., bequeathed to the Society the sum of £100, free of legacy duty. This now stands in £93 11*s.* 1*d.* Swansea Corporation 3½-per-cent. Stock.

Trust Funds.

The Lee and Janson Fund: In 1834 John Lee, Esq., LL.D., gave £100, and in 1876 T. C. Janson, Esq., bequeathed £200, the interest to be given to the widow or orphan of a deceased Fellow. These amounts now stand in £334 10*s.* 9*d.* East Indian Railway 3-per-cent. Debenture Stock.

	£	*s.*	*d.*		£	*s.*	*d.*
1913 Jan. 1. Balance of Fund	74	17	10	1913. Grants to Mrs. M'Dowell	9	0	0
Dividends, East Indian Railway	10	0	9	Grants to Mrs. Henkel	7	0	0
				Grant to Mrs. Smart	10	0	0
				1913 Dec. 31. Balance of Fund	58	18	7
	£84	18	7		£84	18	7

The Turnor Fund and the Horrox Memorial Fund: In 1853 the Rev. Charles Turnor, M.A., bequeathed a sum of £500, which now stands in £464 18*s.* East Indian Railway 3-per-cent. Debenture Stock. In 1876 the Society received a sum of £38 15*s.*, the unexpended balance of a fund collected for the purpose of erecting a memorial in Westminster Abbey to Jeremiah Horrox: to this the Society added the sum of £55 15*s.*, and the whole now stands in £103 6*s.* East Indian Railway 3-per-cent. Debenture Stock. The interest on these funds is to be used in the purchase of books for the Library.

	£	*s.*	*d.*		£	*s.*	*d.*
1913 Jan. 1. Balance of Fund	1	13	4	1913. Purchase of Books	10	0	0
1913. Dividends, East Indian Railway ...	17	1	0	1913 Dec. 31. Balance of Fund	8	14	4
	£18	14	4		£18	14	4

The Hannah Jackson (née Gwilt) Fund: In 1861 Mrs. Hannah Jackson (*née* Gwilt) gave £300 Consols, which now stands in £309 18*s.* 6*d.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be given in medals or other awards in accordance with the terms of the Trust.

	£	*s.*	*d.*		£	*s.*	*d.*
1913 Jan. 1. Balance of Fund	50	0	5	1913. Casting 5 medals, etc.	12	16	0
Dividends, East Indian Railway	9	6	0	Grant to Rev. T. E. Espin	30	0	0
				1913 Dec. 31. Balance of Fund	16	10	5
	£59	6	5		£59	6	5

Assets and Present Property of the Society, 1914 January 1.

	£	s.	d.	£	s.	d.
Balances, 1913 December 31 :—						
At Bankers', as per Pass-book	232	4	4			
,, on deposit	60	0	0			
Cheque not credited till 1914	2	2	0			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	1	12	6			
In hand of Assistant Secretary on Petty Cash Account	4	19	8			
				300	18	6
Due on account of Subscriptions :—	£	s.	d.			
14 Contributions of 3 years' standing	88	4	0			
36 ,, 2 ,, ,,	151	4	0			
66 ,, 1 ,, ,,	138	12	0			
Other sums	9	18	0			
	387	18	0			
Less Contributions paid in advance	6	6	0			
				381	12	0
Due from Wm. Wesley & Son for sales of Publications during last quarter of 1913				20	17	0

£1,250 Metropolitan 3-per-cent. Stock.

£2,000 Swansea Corporation 3½-per-cent. Stock (including the McClean and Farrar Bequests).

£3,500 East Indian Railway 3-per-cent. Debenture Stock (including the Turnor Fund, the Horrox Memorial Fund, the Lee and Janson Fund, and the Hannah Jackson (*née* Gwilt) Fund).

£3,500 London and North-Western Railway 3-per-cent. Debenture Stock (including the Carrington Bequest).

£4,000 Midland Railway 2½-per-cent. Debenture Stock.

£1,000 Lancashire and Yorkshire Railway 3-per-cent. Consolidated Preference Stock.

£2,400 Gas Light and Coke Co. 3-per-cent. Debenture Stock.

£2,000 Commercial Gas Co. 3-per-cent. Debenture Stock.

Astronomical and other Manuscripts, Books, Prints, Photographs, and Instruments.

Furniture, etc.

Stock of Publications and Photographs.

Three Gold Medals.

Celestial Photographs.

No additions have been made to the list given in the last Report.

The Award of the Gold Medal.

The Council have awarded the Society's Gold Medal to Professor Max Wolf, for his work in Celestial Photography and Spectroscopy. The President will lay before the Society the grounds upon which the award has been founded.

Publications of the Society.

During the past year vol. lxxiii. of the *Monthly Notices* has been published.

The following part of the *Memoirs* has also been published:—

Vol. lx. part iii. Stellar Photographs by the late John Franklin-Adams.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year :—

Fellows :—Arthur Henry Baker.
* Sir Robert Stawell Ball.
Penry Vaughan Bevan.
Archibald Cuthbert Bigg-Wither.
The Earl of Crawford.
Thomas Cushing.
Lindsay Atkins Eddie.
Frederick William Henkel.
Robert Killip.
Thomas Henry Leale.
Edmund Ledger.
Jonadab McCarthy.
Legh Richmond Powell.
Friedrich Wilhelm Ristenpart.
David Smart.
† Lewis Swift.
Thomas Robert Terry.
Edward Tyer.
Edward John White.
Hugh Williams.
Associates :—* Seth C. Chandler.
Julius Franz.
Julius Scheiner.

* Obituary deferred.
† Obituary in last Annual Report.

Arthur Henry Baker was born at Star Cross, Devon, on 1857 April 28. In 1876 he entered Cheltenham Training College as the senior student of his year, and, on leaving College, was appointed Assistant Master at Ann Street School, Clerkenwell. Always a keen and enthusiastic student, he graduated B.A. at the University of London in 1887. In 1888 he was appointed Assistant Master at the Southwark Pupil Teachers' Centre in Bermondsey, where he found fuller scope in educational work. He was an enthusiastic and capable teacher, and was held in high esteem by his pupils and colleagues.

Mr. Baker's interest in astronomy was quickened by his teaching of physiography, in connection with which he attended a short course of instruction under Sir Norman Lockyer at South Kensington. In 1895 he was promoted to the Headmastership of Basnett Road School, Battersea, over which he presided till his death. His intellectual power and natural enthusiasm found vent in the

practical turn he gave to the studies of his pupils and in the flourishing Old Boys' Club, which is a strong local feature. His arduous labours as Hon. Secretary for many years of the Pupil Teachers' University Scholarship Committee, and his efforts as author of well-known books on arithmetic deserve mention. His entire unselfishness and his abiding loyalty to his friends endeared him to a very wide circle. He died at Clayden, Bucks, on 1913 March 29, leaving a widow, one son, and one daughter.

He was elected a Fellow of the Society 1900 November 9.

Penry Vaughan Bevan was born in London on 1875 February 20. He entered Cambridge University in 1896, was fourth Wrangler in 1899, and was placed in the first division of the first class in part ii. of the Mathematical Tripos in the following year. He then joined the band of researchers in experimental physics working under the guidance of Sir J. J. Thomson. In 1901 he was appointed to a demonstratorship at the Cavendish Laboratory, and was elected a Fellow of Trinity College in 1902. His most important investigation at Cambridge dealt with the action of light on the rate of combination of hydrogen and chlorine.

On his removal to London in 1908, when he became Professor of Physics at the Royal Holloway College, he took up the subject of spectroscopy with great enthusiasm, and made several valuable investigations, the results of which were published by the Royal Society and by the Physical Society. By improved experimental arrangements he observed important extensions of the principal series lines in the absorption spectra of lithium, rubidium, and cæsium, which he utilised in comparative tests of the various formulæ which had been suggested for series lines. He also gave considerable attention to experiments on anomalous dispersion in the vapours of the alkali metals, and in a communication to the *Monthly Notices* (lxxii. p. 84) he discussed the possible bearing of these observations on the interpretation of solar phenomena.

Professor Bevan was for a time President of the Cambridge Nonconformist Union, and afterwards took an active part in the Students' Christian Movement. He was a Recorder of Section A at the Birmingham Meeting of the British Association in 1913.

His death on 1913 December 15, at the early age of 38, cut short a life from which much valuable scientific work had been confidently expected.

He was elected a Fellow of the Society on 1911 January 13.

Archibald Cuthbert Bigg-Wither was born on 1844 September 25 at Tangier Park, near Basingstoke. He was the ninth son of Lovelace Bigg-Wither of Manydown and Tangier Parks, Hampshire, where the family had resided since the fifteenth century. On his mother's side he was the great-grandson of Guy Carleton, first Baron Dorchester, one of the makers of Canada. He was educated at Temple Grove School, Surrey, and at Marlborough College.

At the age of seventeen he went to India, and was attached to the 52nd Light Infantry as an Ensign for regimental duty. In the following year he was promoted to the rank of Lieutenant and joined the 3rd Punjab Infantry.

In 1865 he entered the Thomason Engineering College for Officers at Roorkee, and passed with honours, gaining two gold medals and a thousand rupees. He was appointed in 1866 to the Public Works Department as Assistant Engineer in the Central Provinces. On his return to India in 1868, after a short absence on leave, he was placed in charge of roads, bridges, and railways in the Central Provinces, the most important being the Grand Trunk Road from Nagpore to Jubbulpore.

While on sick leave in England in 1871 he married the younger daughter of Capt. Rolston, of the Madras Army. On his return to India in 1872 he was appointed Personal Assistant to the Chief Engineer of the Indus Valley Railway, with headquarters at Mooltan, where he remained for seven years. After two years' leave he was sent to Julpaiguri as Executive Engineer, and in 1882 was transferred to Calcutta as Superintendent of Works. Three years later, Major Bigg-Wither was promoted to the rank of Superintending Engineer, and transferred to the Frontier Province of Beluchistan, with headquarters at Quetta, where he was stationed for seven years, under the late Sir Robert Sandeman. He brought water into Quetta, and accompanied his chief into the newly acquired country of Zhob, where he built forts and bridges, and the Civil and Military buildings. He also reopened the old and important trade-route through the Gornal Pass. For these services he received the thanks of the Government of India.

In 1894, after two years' leave, Colonel Bigg-Wither was sent to Assam as Superintending Engineer and Secretary to the Chief Commissioner, but he returned to Bengal in 1895. He retired in 1896, and settled near Godalming, in Surrey, where he was much devoted to cycling.

Colonel Bigg-Wither was from early youth an enthusiastic astronomer. He had an observatory of his own for nearly 45 years, containing a 5-inch telescope and a transit circle, which were in constant use for observations of all kinds. At Quetta and Mooltan his observatory was the scientific centre of the Civil and Military stations. After a long day in the Public Works Department he would be invariably found in the midst of calculations or working with his instruments till the night was far advanced. In 1874 he observed the transit of Venus in perfect weather, and scores of persons flocked to his observatory to watch the passage of the tiny black disc across the sun. His observations were published in *Mem. R.A.S.*, vol. xlvii. p. 97. As the sun rose with Venus already on the disc, there was no observation of ingress, but remarkable phenomena were recorded at internal contact at egress.

After his retirement, Colonel Bigg-Wither resumed his astro-

nomical work, and frequently attended the meetings of the Society. He also attended many of the meetings of the British Association, including those held in South Africa and Canada.

He died in the Isle of Man on 1913 September 23, leaving a widow, two sons, and a daughter.

He was elected a Fellow of the Society 1869 January 8.

James Ludovic Lindsay, 26th Earl of Crawford, and 9th Earl of Balcarres, Lord Lindsay of Balcarres, and Baron Balniel, in the peerage of Scotland, and Baron Wigan in the peerage of the United Kingdom, was born on 1847 July 28, at St. Germain-en-Laye, France. He was educated at Eton, and at Trinity College, Cambridge, where he devoted himself especially to astronomy. In 1870 he observed the eclipse of the Sun at Cadiz, and two years later, with the cordial co-operation of his father, he commenced the erection of the afterwards famous observatory at Dun Echt, in Aberdeenshire. Here he installed an $8\frac{1}{4}$-inch meridian circle by Simms, a 15-inch equatorial telescope by Grubb, and a liberal supply of spectroscopes and other accessories. In planning and equipping the observatory he was fortunate in securing the co-operation of the late Sir (then Mr.) David Gill, then resident at Aberdeen, whose growing reputation as an observer had attracted the attention of Lord Lindsay and his father. Gill was put in charge, and was connected with the observatory in the very active years of its foundation and during the Transit of Venus expedition of 1874.

From 1876 to 1889, the astronomer in charge at Dun Echt was Dr. Ralph Copeland, with Mr. J. G. Lohse, and subsequently with Mr. (now Professor) L. Becker, as assistant. The observatory became well known as a centre of astrophysical research, and many valuable observations of the spectra of comets, stars, and nebulæ were secured. The "Dun Echt Circulars" were for some years an important source of early information relating to astronomical phenomena; the last, No. 179, was dated 1890 January 29.

A characteristic feature of Dun Echt Observatory was the magnificent library, one of the finest collections of astronomical books in the world, and especially rich in ancient and rare works.

Before his succession to the earldom, Lord Crawford took an active personal share in the work of the observatory, and also organised, at great expense, an expedition to Mauritius for observations of the Transit of Venus in 1874, on which he was accompanied by Gill and Copeland. The observations of the Transit itself were marred by the weather, but the expedition secured extensive determinations of longitudes, and a preliminary attempt was made to determine the solar parallax from observations of the minor planet Juno. Not much importance was attached to the results for the parallax, but the value of the method was established, and Gill subsequently put it to excellent use.

The results of the Mauritius observations are contained in the second and third volumes of the "Dun Echt Observatory Publications," the first volume of which was a summary of Struve's

Mensuræ Micrometricæ, conveniently rearranged to meet the needs of double-star observers. Many papers emanating from Dun Echt were communicated to the *Monthly Notices*.

Lord Crawford succeeded his father in 1880, and soon afterwards ceased to reside at Dun Echt, which he had determined to sell. On coming into possession of his uncle's property at Balcarres he determined to rebuild the observatory there, and a site was actually settled upon, when circumstances arose which diverted his plans. In 1888 Piazzi Smyth resigned his professorship and post as Astronomer Royal for Scotland, which carried with it the charge of the small ill-equipped observatory on the Calton Hill. The future was hanging in the balance and probably the small support then given by the Government would have been withdrawn altogether had not Lord Crawford come to the rescue by offering the whole of his magnificent collection of instruments and books as a gift to the nation, subject to the condition that the observatory should be rebuilt upon a suitable site and maintained in a proper manner. By this noble offer the creation of the present fine Royal Observatory on Blackford Hill was made possible; and by it, as much as by his previous work at Dun Echt, Lord Crawford contributed in no small degree to the progress of astronomical science. An interesting account of the circumstances was given by Lord Crawford at the opening of the new Royal Observatory in April 1896.

The most important part of this gift was the library, containing some eleven thousand printed books besides a collection of very valuable Latin MSS. The nucleus of this library had been formed by the library of the late Charles Babbage, and many rare books were added from the library at Haigh Hall. The collection is especially rich in Comet literature. Lord Crawford never lost an opportunity of securing essays and tracts on Comets. Fifty-four pages of the very fine catalogue of the library are occupied by this subject alone.

Lord Crawford was also well known as an enthusiastic yachtsman. In 1901 he purchased the steam yacht *Valhalla*, with which he won third prize in an ocean race from New York to the Lizard in 1905. In the following winter he made a long and memorable voyage, during which he visited South America, South Africa, Ceylon, and Madagascar, and took the mails to remote Tristan da Cunha. This was essentially a scientific undertaking, and the most important British enterprise of the kind since the great expedition of the *Challenger*. Several naturalists accompanied Lord Crawford, and many valuable specimens were subsequently presented to the British Museum, of which he was a trustee.

Lord Crawford was also a noted bibliophile and philatelist. His library at Haigh Hall, Wigan, was one of the finest private collections of literary treasures in the world; a large portion of it was some years ago dispersed by auction. He was chairman of the Wigan Free Library for 35 years, during which time he enriched it with many valuable gifts. His early interest in the collection of stamps was renewed in 1900, when he purchased a

collection at Messrs. Sotheby's. The most remarkable of his subsequently large collections included the stamps of Great Britain, the United States, and the old Italian States. He also formed a large philatelic library, which he left to the British Museum.

In 1878 and 1879 Lord Crawford was President of the Royal Astronomical Society in succession to Sir William Huggins. He was elected a Fellow of the Royal Society in 1878, and an Honorary Associate of the Prussian Academy of Sciences in 1883. He was much interested in photography, and was President of the Royal Photographic Society from 1896 to 1900. In 1910 he succeeded the present King as President of the Royal Philatelic Society.

From 1874 to 1880 he represented Wigan in the House of Commons, and afterwards sat in the Upper House as Lord Wigan.

In 1869 Lord Crawford married Emily Florence, second daughter of Colonel the Hon. Edward Bootle-Wilbraham, and granddaughter of Edward, first Baron Skelmersdale. He died on 1913 January 31, leaving five sons and a daughter.

He was elected a Fellow of the Society on 1871 January 13.

Thomas Cushing was born at Islington in 1840. He was educated privately. From an early age he showed an interest in science, and in 1863 was appointed to a junior post in the firm of Thomas Cooke & Sons of York. In 1867 he entered the service of the India Office, and was appointed assistant inspector of scientific instruments at the India Store Depôt; on the death of Colonel Strange in 1876 Mr. Cushing was appointed his successor. Up to this time the instruments required for India were mainly those connected with the great surveying work carried on in that country, but electrical apparatus now began to assume the great importance it has since attained. Mr. Cushing became more and more constantly occupied in testing and sending out electrical instruments, from telegraphic apparatus to large electrical installations. About 1902 some difficulty occurred in connection with a long telegraph line, owing to inadequate insulations, and he therefore designed a new form of insulator, specially suited to the climate of India, by which the defects were successfully overcome. He also invented and patented the Cushing reversible level, for which he received a Government reward. His work increased so much that an assistant inspector was appointed in 1903. By his unfailing kindliness he endeared himself to his colleagues and all those with whom his official duties brought him in contact.

After his retirement in 1905, he spent some years in Hanover, and then took up his residence at Woodside, where he lived till his death. He was active in all local matters, but especially those connected with technical education, and was one of the founders of the Croydon Polytechnic. His duties at the India Office had brought him into contact with the late Mr. W. F. Stanley, who became his intimate friend, and consulted him with regard to the founding of the Stanley Technical Trade Schools and Halls, of which Mr. Cushing became one of the Governors.

Mr. Cushing died on 1913 October 22, and leaves a widow, a son, and three daughters.

He was elected a Fellow of the Society 1879 January 10.

Lindsay Atkins Eddie was born in South Africa in 1845. His father, Dr. W. C. Eddie, M.A., was an army surgeon, and his mother was a sister of the late Sir John W. Kaye, K.C.S.I., F.R.S., and also of the late Lieut.-General Sir Edward Kaye, K.C.B. Major Eddie's early years were passed in Grahamstown, where he had the good fortune to study for some time under the guidance of Dr. Ricards, afterwards Bishop Ricards.

It was through his association with Dr. Ricards that Major Eddie developed an interest in astronomical pursuits. He became a keen observer, and set up a $9\frac{1}{2}$-inch reflector, with which he made many useful observations. He gave special attention to comets, of which he observed no less than twenty-one. Some of his results were communicated to the *Monthly Notices* in seven papers, and others were described in various scientific journals. He contributed to the *Monthly Notices* a long series of observations of Comet *b*, 1882, from September 13 to December 14. These are especially valuable as they contain a very full and minute description of the appearance of the comet in his telescope. He also communicated a paper on the Transit of Mercury, 1894 November 10 (*M.N.*, vol. lv. p. 80). At the opposition of Mars in 1907 he made careful studies of the planet, and his observations received high commendation from M. Antoniadi in the report of the Mars section of the British Astronomical Association, where some of the drawings were published. Major Eddie was also greatly interested in meteorology, and was an expert with the microscope and camera.

His active military service, exclusive of his attachment to the staff during the South African war, extended over twenty years. For his work in the organisation and command of the Grahamstown Rifles during the Kafir invasion of 1876 he was awarded the Kafir medal and clasp. In 1885 he was a lieutenant in command in the Bechuanaland expedition under Sir Charles Warren, and received great praise for his effective services. He was long attached as Judge's Registrar and Secretary to the Judge President in connection with the Eastern Districts Court.

He died at Grahamstown on 1913 October 13.

He was elected a Fellow of the Society on 1880 May 14.

Frederick William Henkel, B.A., was born on 1869 March 22 From an early age he was interested in astronomy and made observations with an old quadrant which he had purchased for a few shillings. His desire to become an astronomer, however, was sternly repressed by his father, who wished him to follow a business career. Nevertheless he managed to increase his knowledge of astronomy by diligent study. In 1897 he obtained a post as Second Assistant at the Oxford University Observatory, where he remained for about eleven months, leaving in the summer

of 1898 to take charge of the Observatory at Markree, Ireland, in succession to Albert Marth. While there, however, he had few facilities for observational work, other than meteorological readings; but he took advantage of the opportunity of extending his knowledge of theoretical astronomy and kindred branches of science. His engagement at Markree was terminated in 1902 by the death of Colonel Cooper, and he returned to London. For a short time he held an appointment in the clerical department of the University of London at South Kensington. After leaving the University, he made a precarious income by writing articles on astronomy for *Knowledge*, *Scientia*, and other scientific journals, and by giving lectures on astronomy.

Mr. Henkel's contributions to the Society's publications included notes on the partial eclipse of the Sun of 1900 May 28, and on the Leonids of 1900 and 1901. His book on "Weather Science" was published in 1911, and received very favourable notices.

Mr. Henkel died after a short illness on 1913 May 22. He leaves a widow and two sons.

He was elected a Fellow of the Society 1890 February 14.

Robert Killip was born at Liverpool on 1853 March 4. As a young man he spent a few years in a Liverpool shipping house, after which he went for a short time to Headingley College, Leeds. He commenced his career as a Wesleyan minister in 1875, when he went as a supernumerary to Northwich. He subsequently served three years in each of twelve circuits, including Liverpool, Manchester, Bradford, and Southport. In 1912 he was superannuated, on account of ill-health, and made Southport his home.

Mr. Killip was an able and cultured preacher, and his services, both as pastor and preacher, were highly appreciated. In private life he was somewhat reserved: but when he was once known he won for himself lasting friendships.

Mr. Killip was a devoted student of astronomy. His instrument was a 5-inch Wray equatorial, and with this he made useful contributions to the work of the Jupiter and Mars sections of the British Astronomical Association, of which he was an active member. In 1905 he went to Burgos in Spain, to observe the solar eclipse of August 30, and was fortunate enough to secure a successful photograph of the corona. As a lecturer on astronomical subjects, Mr. Killip was particularly clear, and his lectures, given without notes, were always welcomed.

Mr. Killip had been in failing health for some time, but the end came suddenly and unexpectedly, on 1913 September 2, when he was on a holiday in the Isle of Man. He leaves a widow, a daughter, and two sons.

He was elected a Fellow of the Society 1896 January 10.

Thomas Henry Leale was born in the parish of Myross, County Cork, in 1838. He was ordained in 1878, and was Chaplain of the Lambeth Infirmary for twenty-six years until his retirement

in 1909. Besides his theological studies, he was a constant student of astronomy and derived much pleasure from the meetings and publications of the Society. For the last three years of his life he was a helpless invalid and was quite blind towards the last. He died on 1913 February 1.

He was elected a Fellow of the Society 1906 January 12.

Edmund Ledger was born in London in 1841 September. He was educated at the City of London School, and at Corpus Christi College, Cambridge; he graduated as Fourth Wrangler in 1863. He was also University Scholar of London University. He was elected Fellow of his College shortly after taking his degree, and remained in residence in Cambridge till 1866, when he accepted the College living of Duxford, Cambridgeshire. He was Rector of Barkham, Ipswich, from 1877 to 1898, when he retired,—afterwards spending the winters at Reigate, and the summers at a cottage near Leith Hill, Dorking. Mr. Ledger acted for many years as an Examiner for the Cambridge Local Examinations. He was Professor of Astronomy at Gresham College from 1875 to 1908, where his lectures drew crowded audiences.

He was the author of *The Sun, Planets and their Satellites*, and of several articles in the *Nineteenth Century* on astronomical subjects.

Mr. Ledger was married, but had no family. He died at Reigate on December 18.

He was elected a Fellow of the Society 1876 February 11.

Jonadab McCarthy, an Irishman by descent, was born at Cheltenham on 1841 December 15. He was for some time a schoolmaster; but, being a man of great imagination and powers of initiative, he early grasped the possibilities of development afforded by his native town. He was the first to commence alterations to existing property on an extensive scale and to acquire important sites, which eventually became of great value. Mr. McCarthy came to London in 1893, and was afterwards a familiar figure in the meetings of the Society. He took a genuine interest in astronomy, and, being an omnivorous reader, there were but few branches of the subject which he had not studied. He had an exceptionally good memory, and is said to have known Milton's *Paradise Lost* by heart.

At the age of twenty-three he married Emma, daughter of M. H. Goldingham, solicitor. She survives him, together with five sons and three daughters.

He died at West Kensington 1913 October 13.

He was elected a Fellow of the Society 1882 November 10.

Friedrich Wilhelm Ristenpart was born in Frankfort-on-Main on 1868 June 8. In early years, while still a pupil at the Gymnasium in Frankfort, he was very much interested in astronomical questions. After leaving school in 1886, he went to the

Universities of Jena and Strassburg, where he pursued his astronomical studies with great zeal. By his thesis presented to Strassburg University for the degree of Ph.D., entitled: "Untersuchungen über die Constante der Praecession und die Bewegung der Sonne im Fixsternsysteme," he entered that range of studies to which he was afterwards almost exclusively devoted, viz. the classical stellar astronomy.

At the end of the year 1891 he became assistant to Professor Valentiner, of the Karlsruhe Observatory. Here and at Heidelberg, to which town the Observatory was transferred in 1896, he took an active part in the numerous observations made at that Institution.

In writing the dissertation above mentioned, he perceived the inconvenience and fruitless waste of time cause by the use of various star catalogues based on different equinoxes. He therefore conceived the idea of uniting into a general catalogue all the positions of fixed stars then in existence. In several letters which passed between him and Auwers the outlines of this work were drawn, and the Prussian Academy of Sciences subsequently granted Ristenpart the subsidies necessary for examining the possibility of the gigantic scheme.

In the beginning of 1898 Ristenpart had accepted a call to the Observatory of Kiel, where the Director, Harzer, most generously left him time enough for the preparation of the *Geschichte des Fixsternhimmels*. The usefulness and possibility of the undertaking having been proved, Ristenpart, in 1900 October, obtained a scientific appointment at the Academy in Berlin, and was entrusted with an office which was under the supervision of a special Committee of the Academy. The first outcome of his work there was the *Fehlerverzeichniss zu den Stern-Catalogen des* 18. *und* 19. *Jahrhunderts*, in which were noted, out of more than 400 star catalogues, all gross errors and many small ones, which were found by him and his collaborators while he was collecting the positions of the stars.

Another work may be mentioned here. If one has to transfer a considerable number of star positions from a certain equinox to another one, the calculation of the usual precession values as coefficients of a series progressing according to powers of the intermediate time is not so convenient as a development according to powers of the tangents of declination, as first shown by Weiss. This method has often been employed in the office of the *Geschichte des Fixsternhimmels*, and Ristenpart took great pains to obtain for it more favour among astronomers by calculating useful tables and by proposing to introduce normal equinoxes, *e.g.* every 50 years.

Another proposal he made had reference to the publication of planet and comet observations. He proved that it is admissible to consider as *mean* comet-place the sum of *mean* star-place and *apparent* difference of co-ordinates. By this method one can save half the calculation of reduction to apparent place.

In 1904 Ristenpart was admitted as Privatdocent of Berlin University, where he found much pleasure in teaching. Now and then he made observations at the Urania Observatory. His predilection for observing activity caused him to accept an invitation to the directorship of the National Observatory, Santiago de Chile, where he found a vast sphere for work. This Observatory was in such a desolate state when he went to Chile that even the amplest reforms could not make it a perfect institution. He therefore advocated the building of a large new Observatory on the site of Lo Espejo, outside of the town. His proposals met with much favour from the Chilian Government, and his projects were especially furthered by the President, Don Pedro Montt. This public-spirited man was greatly interested in all sciences, and he generously helped Ristenpart to overcome the considerable financial difficulties.

Ristenpart then began to educate a staff of observers and computers for the varied work of the Observatory. Several great series of observations with the meridian circle, the refractor, and the transit instrument were started. At first all went well, and the progress of his work was astonishing. But when, on 1910 August 16, Pedro Montt suddenly died, the organisation of the Observatory had lost its most active friend and promoter. Owing to the other difficult tasks to be fulfilled by a young country, the interest of the leaders soon waned, and in the last year Ristenpart could scarcely obtain the means necessary for continuing the work which he had already established. His working power, formerly almost without limits, now failed him; his health became more and more precarious, and the prospect of seeing all his projects and hopes wrecked may have caused him to estimate his life worthless. On the morning of 1913 April 9 he voluntarily sought death.

Ristenpart was twice married. He leaves a widow, a son, and three young daughters.

He was elected a Fellow of the Royal Astronomical Society 1912 June 14.

[For the above notice the Council are indebted to Dr. Prager, who was formerly assistant to Dr. Ristenpart at Santiago.]

David Smart was born at Welwyn in Hertfordshire on 1848 September 18. In 1850 his parents left Welwyn for Lakenheath, Suffolk, where, as a little boy, he delighted in watching the stars and took the greatest interest in anything connected with astronomy. He could read at three years of age. His first school was at Stamford in Lincolnshire; from there he went to Denmark Hill Grammar School, and for a short time to Cranbrook Grammar School when he lived in that town. From there he entered as a student at St. Bartholomew's Hospital; he never failed at an examination, and passed his M.R.C.S. Eng. and L.R.C.P. Lond. as soon as he was twenty-one years of age. Having been elected resident House Surgeon to the Surrey Dispensary, he was obliged to take his L.S.A.

At the age of twenty-five he married Miss Mary Thomas, of Usk, and settled down to the practice he bought of Dr. Dixon in the Grange Road, Bermondsey, where he died nearly forty years afterwards. Having a suitable garden, he bought and erected one of Calver's 10-inch reflectors. This was a great source of pleasure to him for years; but latterly the atmosphere of London was too dense for outdoor researches. He was one of the founders of the British Astronomical Association, and for sixteen years was a member of the Council. He prepared the memoir on the observations of Halley's Comet at the recent return, undertaking this heavy work at the request of the Director of the Comet Section. It involved the discussion and condensation of a very large amount of observational material. He was also a member of several of the observing sections of the Association, and some of his drawings and notes are contained in its Memoirs.

He did not communicate any papers in his own name to the Royal Astronomical Society; but Dr. Crommelin has stated that he deserves to be considered a joint author of the series of papers on "The Perturbations of Halley's Comet in the Past," viz. from 240 B.C. to A.D. 1531 (*M.N.*, vol. lxviii.). In conjunction with Mr. F. R. Cripps and Mr. Thomas Wright, he undertook a very large share in the computation of the planetary perturbations. This was to him a labour of love; he took a most lively interest in the progress of the work, and his computation sheets were a model of method and order.

Dr. Smart was Consulting Surgeon to the Surrey Dispensary, Medical Officer to St. Olave's Workhouse, and Public Vaccinator. No doubt the stairs he had to climb at the workhouse and in the model buildings brought on the heart trouble which proved fatal on 1913 March 27. He left a widow, two sons, and a daughter.

He was elected a Fellow of the Society 1889 December 13.

Thomas Robert Terry was born in 1849, and was educated at St. Peter's School, York. He went to Trinity College, Cambridge, with a minor mathematical scholarship, and was placed fifth among the Wranglers in 1873. Two years later Mr. Baring nominated him to one of his new open scholarships at Hertford College, Oxford. At Oxford Mr. Terry took a first-class in Mathematical Moderations, and won the Junior Mathematical Scholarship. In 1877 he was elected to an open Fellowship in Mathematics at Magdalen College. He resided there as a Fellow for seven years, acting for short periods as Junior Dean and Home Bursar, Mathematical Master at the college school, Mathematical Moderator and Public Examiner in Mathematics, and Mathematical Lecturer at Brasenose College. He contributed to the *Proceedings of the London Mathematical Society*.

Mr. Terry took holy orders in 1879, and was presented by his College in 1884 to the living of East Ilsley, Berks, where he was greatly esteemed. In the summer of 1912 his health broke down,

and he retired to Oxford. He died suddenly on 1913 May 3, leaving two sons.

He was elected a Fellow of the Society 1881 March 11.

Edward Tyer was born at Kennington on 1830 February 6. He was educated first at the City of London School and afterwards at the private school of Mr. Dempster near Chiswick, where scientific studies appear to have received unusual attention. Mr. Tyer was especially attracted by experiments on electricity, and he turned his knowledge to good account in later years in the development of telegraphic signalling for the regulation of railway traffic. He became manager of the Railway Electrical Signals Company in England and of Winkworth & Cie in France, and made many inventions in the course of his work. The "tablet" system invented by him was widely adopted at home and abroad, and he is said to have probably done more than any man of his time to secure the safety of railway passengers.

Mr. Tyer also took a prominent part in the development of telegraphic inter-communication in London. It is interesting to recall that before 1859 the people of London could not communicate with each other by telegram, and could only make use of the trunk lines by taking their messages to central offices. This state of things was remedied by the London District Telegraph Company, of which Mr. Tyer was appointed electrical engineer. The laying down of underground and overhead wires by this Company laid the foundation of the system afterwards perfected under the management of Sir William Preece.

Mr. Tyer's interest in astronomy was aroused when his professional work brought him in contact with Sir George Airy, in connection with the establishment of telegraphic communication between the Royal Observatory and the outside world. His interest took a practical turn, and for many years he had a well-equipped private observatory. He was an Associate of the Institution of Civil Engineers, a member of the Institution of Electrical Engineers, a Fellow of the Royal Microscopical Society, and a Fellow of the Royal Geographical Society.

He died on 1912 December 25, leaving two daughters, a son, and a grandson.

He was elected a Fellow of the Society 1864 November 11.

Edward John White was born at Bristol on 1831 December 8. He was educated at Queen Elizabeth Hospital, and went to Australia in 1853. He was an engineer by profession, and superintended the erection of some of the earliest mining machinery in Bendigo, Victoria. He subsequently became Chief Assistant at the Melbourne Observatory, and it was largely due to his labours that this institution took so conspicuous a place among Australian observatories. Mr. White was chiefly responsible for the Melbourne star catalogues, and was the author of many papers on astronomical subjects. In 1875–76 he was Acting Government

Astronomer of Victoria, and he was in charge of the party for observing the Transit of Venus at Hobart in 1882. He retired from observatory work some years before his death, but continued to reside in close proximity to the Observatory.

He died on 1913 August 2, leaving a widow and family.

He was elected a Fellow of the Society 1869 January 8.

Hugh Williams was born at Wallasey in 1874. He chose the sea as his profession, and secured his master's and extra-master's certificates as quickly as the Board of Trade regulations would allow. In 1905, as a lieutenant in the Royal Naval Reserve, he was appointed for twelve months' training to H.M.S. *Venus*, then attached to the Mediterranean Squadron under Lord Charles Beresford. He became especially interested in astronomy when the *Venus* was despatched to Palma, Majorca, to assist Sir Norman Lockyer's party in securing observations of the Total Eclipse of the Sun on 1905 August 30. Lieutenant Williams took charge of the arrangements for observing the "shadow bands," and interesting records of the phenomena were secured.

On his return to Liverpool in 1906, Lieutenant Williams was appointed assistant to the chief surveyor of the Liverpool Salvage Association, in which capacity he served with great ability and distinction. He was engaged upon many important salvage cases, including those of H.M.S. *Montagu* on Lundy Island, H.M.S. *Gladiator* in the Solent, the Cunard liner *Ivernia* in Queenstown Harbour, and, finally, the R.M.S.P. Co.'s steamer *Agadir* near Mazagan, Morocco. It was through the operations on the *Agadir* that he lost his life. In spite of much suffering caused by poisonous gases liberated from saturated grain forming part of the general cargo, Lieutenant Williams remained hard at work, and eventually succeeded in floating the vessel and getting her to Gibraltar. He then collapsed, and was conveyed to the civil hospital. Complications ensued, and he died on 1913 June 9th. He leaves a widow and three young boys.

He was an Associate of the Institute of Naval Architects and a younger Brother of Trinity House.

He was elected a Fellow of the Society 1909 November 12.

Julius Heinrich G. Franz died after a long and painful illness from heart disease on 1913 January 28. He was born at Rummelsburg in Pomerania on 1847 June 28, the son of a distinguished physician. His university studies were made at Greisswald, Halle, and Berlin, and he devoted himself to natural science and mathematics, specialising in elliptic functions. During the Franco-Prussian War of 1870, being unfit for military service, he turned his energies to teaching, finally becoming an assistant-master at Berlin. There also he attended the lectures of Tietjens and calculated the orbits of minor planets. His first astronomical appointment was that of assistant to Professor Foerster at Neuchâtel in 1874, where he devoted his attention mainly to

meridian observations. Two years later he joined the staff at Koenigsberg, where he stayed until his appointment to the directorship of the Observatory at Breslau, in succession to Galle, in the year 1897. He also became extraordinary professor. In 1882 when at Koenigsberg he took a prominent part in the observation of the transit of Venus at a station at Aiken in South Carolina. His other earlier astronomical work is represented by a fairly large number of contributions to the pages of the *Astronomische Nachrichten*, concerned principally with astronomy of position. He also made a considerable number of heliometer measures of double stars. The articles on astronomy in the *Year-Book of Natural Science* for the years 1887–1898 were likewise from his pen. But his chief work was in connection with the figure and libration of the Moon. This is contained in two volumes issued from the Observatory of Breslau under his directorship. In the first of these he gives the positions of no less than 150 lunar craters measured on five lunar photographs, and in the second discusses his original methods for measuring positions on the satellite by means of the heliometer. The results of all his prolonged studies of selenography are summed up in his well-known work *Der Mond*, published in 1906, and in that on the Moon's libration recently published in 1913. These observations and reductions, and their presentment in the papers and works detailed above, were made in such leisure hours as he could secure from his duties as a professor, which he ever regarded as paramount. Even when attacked by his final illness he had his measuring machine brought to his sick-room, so that in the hours of freedom from pain he might work at his favourite science. His personal character was marked by the traits of cheerfulness and unselfishness, indications of his warm-hearted attachment to his friends.

He was elected an Associate of the Society on 1906 June 8.

A. L. C.

Julius Scheiner was born in Cologne on 1858 November 25. After attending the elementary school and gymnasium at Dentz he went to the college at Cologne, where the instruction in physics was given by Professor Schellen. Notwithstanding the interruption of his studies by ill-health, Scheiner was one of the best of pupils and developed special skill as an experimentalist. He afterwards proceeded to the University of Bonn, and resolved to devote himself to astronomy, for which a special inclination had been aroused by a visit to the Bonn Observatory during his school-days. He was one of Schönfeld's most capable students, and soon became able to take part in the regular observations and to increase his scanty income by undertaking computations. He was appointed an assistant at the Bonn Observatory in the autumn of 1881.

In March 1882 Scheiner graduated with his dissertation "Untersuchungen uber den Lichtwechsel Algols nach den Mannheimer Beobachtungen von Professor Schönfeld in den Jahren

1869–1875." On the conclusion of his year of military service, which had a good effect upon his health, he applied himself zealously to the work of the Observatory, and won the high regard of his chief. Among other investigations during this period he made experiments bearing upon the effect of the Purkinje phenomenon on the limit of visibility of stars of various colours.

On the invitation of Dr. H. C. Vogel, Scheiner went to the Astrophysical Observatory at Potsdam on 1887 January 1. He was much impressed by the equipment of the Observatory, and entered on his new duties with enthusiasm. In company with two of his colleagues, he went to Russia in August 1887 to observe the total eclipse of the Sun, but, as at all other stations in Russia on that occasion, observations were prevented by bad weather.

Vogel enlisted the co-operation of Scheiner when he initiated the determination of stellar velocities by photographic methods. Scheiner's practical skill specially fitted him for this important undertaking, and the work was soon crowned with success. The photographic method was firmly established, and the radial velocities of numerous bright stars were determined with an accuracy far surpassing those deduced from visual observations. Of special interest was the first determination of the orbit of a spectroscopic binary from periodic displacements of the spectrum lines, made by Vogel and Scheiner in 1889, when they confirmed the eclipse theory of the variability of Algol, and deduced the dimensions and mass of the system without a knowledge of the parallax.

Scheiner applied himself to a great variety of problems in the domain of astrophysics. He made measures of the Sun's radiation with an Ängström pyrheliometer, and found the "effective temperature" of the Sun to be 6196° to 6252°. Later, in conjunction with Dr. Wilsing, he made an important series of spectrophotometric determinations of the temperatures of 109 stars, confirming in the main the generally accepted evolutionary sequence deduced from the sequence of spectral lines. Accounts of his various researches occupy an important place in the publications of the Potsdam Observatory.

Scheiner was the author of several books, of which *Spektralanalyse der Gestirne*, published in 1890, is well known to English readers through the translation by Frost; this was the first textbook of importance dealing with the new branch of astronomy, and has long been a valuable work of reference. In 1897 he published the *Lehrbuch der Photographie der Gestirne*, and in 1899 a smaller work, *Strahlung und Temperatur der Sonne*; and finally, in 1909, *Darstellung der spektralanalytischen und photometrischen Theorien*. He also prepared many coloured plates of spectra from observations by Vogel, illustrating the spectra of comets, nebulæ, and typical stars, of which an English edition has been published by A. Hilger, Ltd. Scheiner had also a marked ability in expressing himself in a form adapted for the general reader; his little book *Der Bau des Weltalls*, was widely read, as was also his

Populäre Astrophysik. He was a frequent contributor to *Der Naturforscher* and other journals, and helped to spread a knowledge of astrophysics by popular lectures.

Though suffering during the whole of his life from a nervous complaint, which could only be relieved by work and exercise in the open air, Scheiner was a particularly sociable man, and those who sought his help learned to value his plain but kindly manner. For some years his eyes had also given trouble, and the heart complaint increased. In the autumn of 1913 he appeared to be recovering, and hoped to return to his work, but the improvement was of short duration, and on 1913 December 20 a paralytic stroke brought a painless death. He leaves a widow and three daughters.

He was elected an Associate of the Society on 1901 November 8.

Proceedings of Observatories.

The following reports of the proceedings of Observatories during the past year have been received from the Directors of the several Observatories, who are alone responsible for the same.

Royal Observatory, Greenwich.
(*Director, Dr. F. W. Dyson, Astronomer Royal.*)

Transit-Circle.—During the year 14,000 observations have been obtained. The Sun has been observed 159 times, and the Moon 98 times. Reflexion observations of stars have been obtained on 90 nights.

The working catalogue of stars contains fundamental stars observable in these latitudes and all stars down to $9^{m}\cdot0$ on the scale of the *Bonn Durchmusterung* for the zone $+24^{\circ}\cdot0$ to $+32^{\circ}\cdot0$. The state of work is well advanced except between 5^{h} and 8^{h} of right ascension, which is comparatively poorly observed in consequence of bad weather in successive years.

Altazimuth.—During the year 1622 meridian transits have been observed. The Moon has been observed 62 times on the meridian, and 12 times in other azimuths.

A new eye-end has been constructed for the instrument by Messrs. Troughton & Simms, and was brought into use in June. It has an impersonal micrometer for the transits and a printing micrometer for the zenith distances. Further, ruled glass plates have been substituted for spider's webs, as, owing to the length of span, the threads broke frequently. The transits show a very satisfactory agreement between the different observers, and the accordance between the four positions of the instruments is close. The systematic error in the zenith distances has largely diminished, but has not entirely disappeared. The observations of stars from $1909\cdot0$ till the installation of the new eye-end have been collected into a catalogue, and will be published in the next annual volume.

Cookson Floating Zenith-Telescope.—During the year 131 plates, each exposed on a group of 4 or 5 Talcott star pairs, have been taken, and also 5 plates for the determination of scale. The total number of plates taken to date with the instrument is 342, (including 14 scale plates), of which 14 have been rejected. The measurement of about one-third of the plates taken in 1913 has been completed. A discussion by Mr. Eddington of the results obtained during the first full year of work was communicated to the Society in June. It appears from this discussion that a good determination

of the aberration constant may be anticipated from a few years' observations on the present lines.

Occultations.—11 disappearances of stars occulted by the Moon were observed by one or more observers. Owing to unfavourable weather no occultation of the Pleiades was observed during the year.

28-inch Refractor.—421 double stars have been measured, each star on the average being observed on two nights. They comprise—

98	double stars	with	separation	$<$	$0''.5$
84	,,	,,	,,		$0''.5$ to $1''.0$
107	,,	,,	,,		$1''.0$ to $2''.0$
132	,,	,,	,,	$>$	$2''.0$

Among the most interesting observations are—

Sirius; observed 1913·14: Position angle 82°·6; distance 10″·03
Procyon; ,, 1913·14: ,, ,, 34°·3.

κ Pegasi was observed on 9 nights; δ Equulei on 3 nights; 70 Ophiuchi on 12 nights; ϵ Hydræ AB on 1 night; β 883 on 3 nights; and β 151 on 7 nights.

Astrographic Equatorial.—165 photographs have been taken with exposures on the Pole and on various fields of the Astrographic Catalogue when at the same altitude. Of these photographs 122 were considered satisfactory for the determination of photographic magnitudes. These plates are the basis for the determination of the photographic magnitudes of the stars in the Astrographic Catalogue fainter than $9^m.0$, those of the brighter stars being obtained from a series of photographs taken with the 6-inch Cooke triplet.

The Catalogue for 1900·0 of the Right Ascensions, Declinations, and Photographic Magnitudes of all stars which have been previously observed with meridian instruments is approaching completion. Zones 82° to 68° have been printed during the year, the total number of stars in the catalogue to this limit of declination being 13170. The copy for press of the remainder (zones 67° to 64°) is prepared with the exception of the determination of the magnitudes for zones 64° to 66°, which is in hand.

A determination of the corrections depending on distance from plate centre to be applied to the measured diameters in the Greenwich Astrographic Catalogue, in deducing photographic magnitudes, has been made, and is published in the *Monthly Notices*, vol. lxxiii. p. 518.

Thompson Equatorial.—This instrument has been employed for the determination of stellar parallax with the 26-inch refractor and for photographic photometry with this telescope and with the 6-inch triplet. For parallax, 282 plates have been taken with two or three exposures of 4 minutes each on 90 stars. Of these 142 have been re-exposed at the end of a half-cycle. The occulting shutter has been used in all cases. Of these plates 62 have been

measured by two measurers, and the measurement of 24 plates has been duplicated. Efforts have been made to obtain the most perfect images which the telescope will give, and the measures give promise of good results.

The photometric work has consisted of short-exposure plates on the Pole and on various fields (6^m on Pole: 6^m on field: 6^m on field: 6^m on Pole) and of long-exposure plates (60^m) on various fields with a diffraction-grating giving a difference of 2·7 mag. The fields photographed are the centres of the Franklin-Adams charts and Kapteyn's selected areas. The following table gives a summary of the year's observations:—

	Taken.	Selected for Measurement.
F.A. chart areas—long exposure . .	44	29
,, ,, short exposure .	49	28
Selected areas—short exposure . .	26	20

During the year 76 plates have been measured; 22 of the long exposures of the F.A. areas, 29 of the short exposures, and 25 of the Kapteyn areas.

The measures of stars in the polar area made on a number of plates have been combined and give the magnitudes of 262 stars within 25′ of the Pole. This list is probably complete to the magnitude $15^m{\cdot}0$, and contains many stars down to $15^m{\cdot}5$. The results are published in the *Monthly Notices* for 1913 November.

With the 6-inch triplet 7 photographs have been taken to complete the programme referred to in last year's report of obtaining the photographic magnitudes of the stars brighter than $9^m{\cdot}0$ in the Greenwich Astrographic Zone. Sixteen plates have been measured, and a good deal of revision and remeasurement made with the view of obtaining two determinations of magnitude for each star. The results from the Pole to declination 75° have been printed, and will be published shortly.

During the year electric motors have been installed to turn the dome and wind the clock weight.

Franklin-Adams Charts.—The total numbers of stars on these plates, based on counts on 25 areas on each plate, have been tabulated. For the Northern plates corrections to the magnitudes have been deduced, which depend on the position on the plate: so that, as soon as the magnitudes on the central areas are known, those on the whole of each plate may be inferred.

During the year 96 plates have been reproduced, 30 paper prints on glossy bromide card on the scale 1° = 15 mm. having been made from each photograph.

Photoheliograph.—Photographs of the Sun have been obtained with the Dallmeyer photoheliograph on 262 days during 1913. In the year ending 1913 October 31, photographs have been received from the Cape for 317 days. Five photographs have been received or are due from Dehra Dûn, and 16 from Kodaikánal. In this way the series of Sun pictures is complete for each day of the year ending 1913 October 31.

The measurement of the Greenwich photographs is complete to December 30, and of the Cape and Indian photographs to July 27. The reductions are completed to June 30.

The solar activity has been even smaller than in 1912, only 12 groups of small spots having been observed during the year, as against 33 in 1912 and 62 in 1911. In 1913 the Sun was free from spots on 316 days, as against 250 in 1912 and 186 in 1911.

The determination of the position of the Sun's axis from the photographs since 1874 has been completed and published.

Time-Service.—This has been carried on as usual, and daily comparison made with the signals from the Eiffel Tower and Norddeich.

Personal.—The Observatory has lost the valued services of Mr. Eddington, who was appointed Plumian Professor at Cambridge in June, and of Mr. Maunder, who retired in October after completing forty years' service. Mr. H. S. Jones, Fellow of Jesus College, Cambridge, was appointed Chief Assistant on July 1.

Royal Observatory, Cape of Good Hope.
(*Director, Mr. S. S. Hough, H.M. Astronomer.*)

Transit-Circles.—The new transit-circle has been employed throughout the year in continuation of the programme commenced in 1912 for the observation of stars contained in the Backlund-Hough list, together with such of Boss's fundamental stars as were not contained in the previous working list.

The following observations have been obtained during the year:—

Observations of Right Ascension:—

Number of meridian transits . . .	6948
Determinations of collimation by collimators	110
,, ,, ,, by reflexion and reversal	22
Determinations of level	712
,, ,, azimuth	136
Observations of Meridian Marks	1330

Observations of Zenith Distances:—

Determinations of Z.D.	6670
,, ,, runs	332
,, ,, nadir	690
,, ,, flexure	53

Included in the number of observations are:—

Observations of the Sun on	143 days
,, ,, Mercury ,,	36 ,,
,, ,, Venus ,,	92 ,,

The non-reversible transit circle has been in use by Mr. J. Voûte, an assistant from Leyden, who arrived at the Cape on September 16. He brought with him a self-registering micrometer and special chronograph which have been adapted for use with this instrument, and after preliminary trials commenced a programme of observations for the determination of stellar parallax on December 5.

The following transit observations have been secured:—

Parallax stars	93
Comparison stars . . .	388
Azimuth stars	14
Time stars	17

in addition to 12 observations of circumpolar stars for the determination of screw-value and 10 determinations of collimation error.

Heliometer.—This instrument has been employed for the observation of major planets at the time of opposition and the following observations secured:—

Opposition of	Neptune .	45 obs. in distance on 8 nights.	
,,	Jupiter .	36 ,, ,, ,, 5 ,,	
,,	Uranus .	32 ,, ,, ,, 4 ,,	
,,	Saturn .	21 ,, in distance 21 ,, ,, position angle 8 ,, of standard stars in distance 8 ,, of standard stars in position angle	on 7 nights.
,,	Mars (1914) .	6 ,, in distance on 1 night.	

Victoria Telescope and Astrophysical Laboratory.—The telescope was used on 158 nights during the year. During April and May, and again during August and September, the spectrograph was dismounted for the purpose of obtaining direct photographs of Jupiter's Galilean satellites near the epoch of quadrature of the planet. 35 plates were obtained, each with 6 images of Jupiter and its four bright moons, and 2 exposures to a selected star region.

Attempts to photograph J VII and J VIII were unsuccessful, owing to unfavourable observing conditions.

A few photographs of Jupiter's sixth satellite and various nebulæ and clusters were secured.

The principal work of photographing stellar spectra for radial velocity determinations was carried on during the remainder of the year, and 151 plates were secured on 111 nights.

30 daylight spectra and 18 focus plates were also obtained.

39 plates of metallic spectra have been taken with the four-prism spectrograph.

Comet Zinner was observed on 4 nights with the Repsold micrometer attached to the 18-inch telescope.

In the laboratory 475 plates have been measured, including

101 solar plates (daylight spectra) for standardisation of stellar standard spectra.

Astrographic Telescope.—With this telescope the following observations have been obtained during the year.

Description of Plate.	No. of Plates.	No. of Exposures.	Duration of Exposure.
Magnitude plates	7	61	various
Jupiter VIII region	4	8	20^s, 20^s
„ „	1	1	35
Hector region	3	5	various
With screen attachment magnitude plates	7	59	„

The Plates of the J VIII region were taken at the request of Mr. Knox-Shaw of Helwân as supplementary to the observations of the eighth satellite of Jupiter made there; those of the Hector region at the request of Professor Strömgren. The "magnitude" plates were of an experimental character, taken primarily with a view to the standardisation of the magnitudes of the Cape Astrographic zones. For this purpose a screen device consisting of a grating of a similar character to that in use at Greenwich has been constructed.

All the magnitude plates, together with a number taken in previous years for a comparison of the Kapteyn areas with the South Pole, have been measured and discussed.

Photoheliograph.—Daily photographs of the Sun to supplement the Greenwich series have been secured on 311 days. In all, 634 negatives were taken, of which 9 have been rejected and the remainder forwarded to Greenwich for inclusion with the Greenwich series.

Occultations.—Fifteen separate phenomena of occultations of stars by the Moon have been observed during the year, viz.:—

Disappearances at dark limb . . .	9
Reappearances „ „	6

Reductions of Meridian Observations. — The reductions of meridian observations to apparent place have been completed to 1913 October 31 in Right Ascension, and 1913 November 30 in Declination. The reductions to mean place have been computed to the end of 1912.

Considerable progress has been made during the year with the formation of a catalogue from the meridian observations of 1905–11, which it is anticipated will be ready for press early in the current year.

Details of the meridian observations with the two transit circles during the years 1905–8 have been forwarded to the printer, and proofs passed for all tabular matter relating to the old instrument and 64 pages relating to the new.

A special discussion has been made of the observations of circumpolar stars with the reversible transit circle in 1911, which includes also a provisional determination of the constant of aberra-

tion. This has been sent to press to form Part 3 of vol. xi. of the *Cape Annals.*

"*Carte du Ciel*" *Reductions.*—The identification of the stars by comparison with the C.P.D. has been completed for 337 plates outstanding from the previous years. The control computations to facilitate the comparison of overlapping areas have been completed for 56 plates during the year, and a comparison of results has been carried out for 1300 pairs of overlapping quadrants. The discordances have been examined and revised for 167 plates.

Vol. i. of the *Cape Astrographic Zones,* containing the rectangular co-ordinates and measures of diameters of stars contained on the Astrographic plates in zone $-41°$, has been passed through the press, and vol. ii., containing similar results for the zone $-42°$, is in the printer's hands. Proof-sheets have already been passed for the first seven hours of R.A.

Miscellaneous.—The time-signal service, meteorological observations, and seismograph records have been maintained as in previous years. A proposal is under discussion for the transmission of a daily time-signal from the observatory for the use of shipping in South African waters through the wireless station at Slangkop.

Royal Observatory, Edinburgh.
(*Director, Professor R. A. Sampson, Astronomer Royal for Scotland.*)

Transit Circle and Clocks.—A great deal of time and attention has been given to the going of the clocks and the more exact determination of their errors. As mentioned in the last report, the cellar which contains the solar clock Riefler and the sidereal clock Dent is now controlled in temperature by an electric thermostat. Except for one or two interruptions, this has worked well, and has kept the temperature sensibly constant at $16°{\cdot}8$ C. throughout the year. A marked effect from this is a great improvement in the rate of Dent; it is often not clear whether Dent or Riefler is keeping the better rate. Riefler's error is determined relatively to Dent, by passing its signal-current through a relay which actuates one of the prickers of the Fuess chronograph, the current from Dent actuating another. This method of comparison is very exact, and the coincidences can usually be read with certainty within 2 seconds, determining the relative error well within $0^{s}{\cdot}01$. It is easily made, and for several months back it has been made every two hours throughout the day and night, giving practically a continuous record of the relative going of the two clocks. With this again is compared the error of Dent relative to the Transit Circle. The results are instructive, and will be published in due course.

The clock Riefler stopped once during the year, on December 24, owing to the snapping of the wire of the rheostat in the winding circuit. The wire had become brittle from the frequent passage of the winding current.

Close study is being made of the error of the Transit Circle, in relation more particularly to time determination. The ordinary method of finding collimation gives also the azimuth of the telescope with respect to the N. and S. collimators. It appears that these are so constant in position that they may be treated as meridian marks. The whole set of errors is taken every day, usually three times, and thus a nearly continuous record kept of their fluctuations. It appears that the short-period changes of level and azimuth are due to superficial temperature changes, and follow the temperature curve with great exactness.

In order to see how far the N. and S. collimators may be taken as a fixed datum, as many observations of polars as possible have been taken throughout the year. The preliminary conclusion is that it is much safer to accept the azimuth of the Transit Circle as determined from the collimators than that from an individual polar.

Wireless Time Signals.—The installation of a wireless receiving plant waited for several months for the consent of the Post Office. Excepting the telephone and electrolytic detector the apparatus was constructed in the Observatory. The aerial is 300 feet long, and runs from the east dome to a mast at the west end of the grounds. The receiving table is in the chronograph room. Signals were first received in the middle of December, and seem quite satisfactory. A good deal of trouble was taken before a satisfactory arrangement was found for carrying to the telephone ticks from any of the Observatory clocks, which should be exactly similar in sound to the scientific signals, or time vernier, sent out from the Eiffel Tower at 11.30 p.m. This is now overcome and perfectly controlled, and very short neat ticks are produced indirectly from the clock Riefler. The constant interval that separates them from the impress of Riefler upon the chronograph tape is under examination.

Solar Spectroscope.—A good deal of time was spent in trying to improve upon the earlier rotation photographs and in tests of the grating. The weather was generally unfavourable, and in particular wind gave a good deal of trouble. It is only on very still days that good definition can be secured. The Director attended the meeting of the Solar Union at Bonn.

Fifteen-Inch Equatorial.—Double star observations have been continued, as far as other occupations allowed. Some exposures were made with the prismatic cameras upon certain nebulæ and stars.

Twenty-four-Inch Reflector.—This instrument has not been used during the year.

Seismograph.—Continuous observations have been kept up, and the results communicated to Shide, upon the same plan as hitherto.

Astrographic Catalogue.—During the year, twenty-two plates have been measured from the Perth, W. A., zones,—nine in zone $-39°$ and 13 in zone $-38°$. Computation of standard co-ordinates for zone $-39°$ is in progress.

Electrograph.—Continuous observations have been made. A paper was published in the *Proceedings of the Royal Society of Edinburgh* (March) upon the similarities of the records obtained from day to day at the Observatory and at the University.

Library.—The books of the library were compared with the catalogue, and several rearrangements were made. A number of rare and unidentified fifteenth-century books were sent to the University Library, Cambridge, for examination, and a description of these and our other fifteen-century books is published by Mr. G. P. Johnston in the *Papers of the Edinburgh Bibliographical Society*, vol. ix.

Staff.—In October, Mr. H. Jameson left the Observatory to take the duty of assistant in the Observatory of Colombo, Ceylon. His successor is not yet appointed.

Armagh Observatory. (*Director, Dr. J. L. E. Dreyer.*)

Nearly all the work done during the year has been connected with the edition of Tycho Brahe's *Opera Omnia*, of which the first volume was published in November last. The series is to comprise thirteen volumes, including all Tycho's published writings as well as all existing letters to and from him, and everything of any value which can be extracted from the great mass of miscellaneous papers and calculations preserved chiefly in the Imperial Library at Vienna. Vols. x.–xii. are to contain all his observations, from the original observing ledgers at Copenhagen, supplemented by extracts from the contemporary fair copy of most of the observations, belonging to the Vienna library. The printing of the observations has also been commenced and will proceed independently of that of the rest of the work. Every endeavour is being made to render this edition as complete as possible, and it will contain a considerable amount of hitherto unpublished matter.

Cambridge Observatory.
(*Acting Director, Professor H. F. Newall.*)

The year has been saddened by the illness and death of Sir Robert Ball, who had been Director of the Observatory since 1892.

The post of Chief Assistant became vacant at Michaelmas by the resignation of Mr. Hinks, on his appointment as Assistant Secretary of the Royal Geographical Society. To meet the need arising from the continued illness of the Director, Professor Newall was appointed Deputy Director in October. W. E. Hartley, M.A., of Trinity College, has been appointed to succeed Mr. Hinks as Chief Assistant.

Meridian Circle.—Owing to unfavourable weather in the early

part of the year and to the heavy demands made by other routine work on Mr. Hartley's time, observational work with the Meridian Circle has been restricted almost entirely to the time-service, only four nights being used for observation of the stars of Gill's Zodiacal Catalogue. The reductions to apparent place are calculated to 1909 April 5 in Right Ascension, and to 1911 May 15 in North Polar Distance, and the reductions to mean place to 1909 February 19.

The Ledger of Zone Catalogue Observations is printed as far as R.A. $21^h\ 40^m$.

Wireless time-signals are now available at the Observatory. The aerial is stretched between the anemometer tower on the roof of the main building and a standard at the north-east corner of the Northumberland Dome. Much of the apparatus was constructed by Mr. Hinks in the Observatory workshop. The time-signals sent out from the Eiffel Tower are received daily and compared with the Graham clock (G) or Dr. Pearson's chronometer (P). The time as determined from these signals is about half a second slow on the G.M.T. deduced from Cambridge transit observations (uncorrected for personal equation), the difference being rather greater when G is used than when P is used. The difference between G and P in this respect is probably due to difficulty in hearing P clearly while wearing the telephone head-piece (the signals from G are received through the telephones). The mean of 69 determinations with G near the times at which transits were observed is $0^s{\cdot}51$ (individual values ranging from $0^s{\cdot}2$ to $0^s{\cdot}9$) and the mean of 54 determinations with P $0^s{\cdot}40$ (the range being from $0^s{\cdot}2$ to $0^s{\cdot}8$). Similar differences are found for the Norddeich signals, but these are not so frequently observed. Further research is necessary before it will be possible to decide how much of the discrepancy is to be accepted as the effect of personality and how much is to be ascribed to error in the adopted longitude of Cambridge.

Dr. Pearson, formerly Fellow of Emmanuel College, has presented to the Observatory a valuable chronometer by Dent, which he used in 1882 on an expedition to observe the transit of Venus in Jamaica. It is an excellent timekeeper, and is proving especially valuable in connection with the receipt of the wireless time-signals.

A large number of books and pamphlets which have been selected at Sir Robert Ball's wish from his private library, have been presented to the Observatory by Lady Ball. These form a valuable addition to the many similar gifts made by Sir Robert Ball during his lifetime to the library of the Observatory.

The manuscript computations made by the late Sir George Darwin in connection with his memoirs on periodic orbits and other researches have been deposited at the Observatory by Lady Darwin, with a view to their being accessible to other investigators in these branches of astronomy.

The usual demonstrations in practical astronomy have been given by the Chief Assistant. During the earlier part of the year Mr. Hinks, as University Lecturer in Cartography and Surveying, also

gave at the Observatory instruction in Field Astronomy. Arrangements have been made by which Mr. C. S. Wright, of Caius College, will utilise the Observatory for continuing this instruction to students of surveying and geography.

In the winter months the Northumberland equatorial is used every clear Saturday night in full term, to show celestial objects to members of the University and friends accompanying them; and it is necessary to open the Sheepshanks equatorial also, when the number of visitors is large. During the present winter, Mr. Rolston, of the Solar Physics Observatory, has given very welcome assistance to Mr. Hartley.

Mr. G. W. Walker, F.R.S., is using a site in the Observatory grounds for making magnetic observations in connection with the repetition of the magnetic survey of Great Britain, under the auspices of the Royal Society and the British Association.

Solar Physics Observatory, Cambridge University.
(*Director: Professor H. F. Newall.*)

On 1913 April 1 the Solar Physics Observatory was transferred to Cambridge. The work of this Observatory is now fused with that which has hitherto been carried on in the Astrophysical Department of the Cambridge Observatory. It is under the direction of Professor Newall. Henceforth the report of work done with the Newall telescope, the Huggins telescopes, and the McClean solar instruments, will be included in the report of the Solar Physics Observatory.

The reconstituted staff consists of Mr. F. J. M. Stratton, Assistant Director; Mr. C. T. R. Wilson, F.R.S., Observer in Meteorological Physics; Messrs. F. E. Baxandall and C. P. Butler, Senior Observers; Messrs. W. E. Rolston and W. Moss, Junior Observers.

The instruments transferred to Cambridge include the 18-inch Foucault heliostat and the South Kensington spectroheliograph; the 6-inch Rowland grating of radius 21½ feet; the 3-foot reflector with silvered mirror by Common; the 6-inch Henry prismatic camera (4 prisms of 45°) and the Hammersley equatorial mounting; and various pieces of apparatus and appliances available for spectroscopic and photographic work, and for use in the laboratory.

The new buildings have been designed by Mr. T. D. Atkinson to satisfy the scientific requirements indicated in detail by the Director. They include the following: (i.) A slate-roofed building which forms a large extension of the Astrophysical building erected in 1910 in connection with the Huggins telescopes. The new part comprises under one roof a laboratory, working rooms for the staff, a dark room, a store room, a record room, a workshop and electric battery room, and a house for the resident attendant. (ii.) A

slate-roofed wooden building, large enough to contain the spectroheliograph when remodelled. (The house for the heliostat was transferred from South Kensington and re-erected on the new site.) (iii.) A brick building with movable dome and double shutters, made by Messrs. Cooke & Sons, for the 3-foot reflector.

The staff at once began work on regular investigations not involving fresh observations; and though the work has been liable to frequent interruptions when the active assistance of the staff was needed in arranging apparatus, making catalogues and inventories, etc., good progress has been made. Firstly, a study of the areas and life-history of Sun-spots from the Greenwich records for 1889–1901 has been undertaken. This work was started by Mr. Butler and Mr. Moss, and has been carried on by Mr. Moss alone since Mr. Butler's attention was turned to the rearrangement of the Rowland grating and other matters. Secondly, in preparation for an atlas of typical stellar spectra with assigned chemical origins of lines, the stock of 743 negatives of stellar spectra that have been transferred from South Kensington was systematically reviewed, and a new descriptive catalogue of the spectra has been made for office reference. This work is under the charge of Mr. Baxandall, assisted by Mr. Rolston. Two notes on points arising in this work have been published by the former: "On the Presence of Europium in Stellar Spectra" (*M.N.*, vol. lxxiv. p. 32); and "On the Presence of Certain Lines of Magnesium in Stellar Spectra" (*Proc. Camb. Phil. Soc.*, xvii. p. 323); and a third paper is in the press.

The spectroheliograph was installed on the new site in September, and routine observations were begun at the end of October. Attempts to secure records of the Sun's disc in this year of reduced activity were made on 17 days, and photographs of the Sun's limb in K_{23} light were obtained on 6 of these days. Mr. Butler, assisted by Mr. Moss, is responsible for the spectroheliograph observations.

The 3-foot reflector is nearly ready for re-erection, certain small alterations having been made in the mounting.

The Newall Telescope.—This instrument was used in the spring by Mr. Stratton, assisted by Mr. Manning, in securing a further series of spectrograms of Nova Geminorum No. 2, and it is now in use for a study of the spectra of certain long-period variables, of Md type, at the time of maximum. The discussion of the photographs of the spectrum of Nova Persei, secured by Professor Newall in 1901, has been completed, but publication of the results is postponed pending the completion of the discussion of the series of spectra of Nova Geminorum. The latter work is nearing completion by Mr. Stratton. A preliminary note by Professor Newall and Mr. Stratton on the presence of enhanced (spark) lines in the early spectrum of Nova Geminorum was published in March (*M.N.*, lxxiii. p. 380).

The Huggins Telescopes.—The work with these instuments has been much delayed by an unfortunate accident by which the new compound prism was broken in the workshop of Messrs. Hilger in

1912 December. It has been replaced by a second prism, which seems to be of excellent quality. The new spectrograph has been completed by the Scientific Instrument Company, and is now being adjusted. It is to be used in connection with the Huggins refractor, and is under the charge of Mr. Rolston.

The McClean Solar Instruments.—The new object-glass, of aperture 12 inches, and focal length 60 feet, has been delivered by Messrs. Cooke & Sons to replace the defective one which has been in use during the last four years.

One of the Zeiss comparators has been lent to Mr. Hubrecht for the measurement of further sets of plates secured by him with the Littrow spectrograph in 1911 June. The measurements are being carried out under his direction by Mr. Tunstall, of the University of Manchester.

Mr. Brunt left the Observatory in the summer to take up a mathematical lectureship in Birmingham University. The results of his work have been published in two papers: "On Anomalous Dispersion in the Solar Atmosphere" (*M.N.*, lxxiii. p. 568); and "On the Sun's Magnetic Field" (*Ast. Nach.*, cxcvi. 169).

Dr. Capstick has concluded his photometric work on spectral lines. The results are being prepared for publication.

Mr. Rossi has been working on the widening of the lines in the hydrogen spectrum under varying conditions, and also on the solar rotation as determined from a series of photographs taken with the Littrow spectrograph in the red region of the spectrum.

Mr. C. T. R. Wilson, F.R.S., joined the staff on October 1 as Observer in Meteorological Physics. He has planned an investigation of some of the phenomena of atmospheric electricity, and the apparatus designed for this work has been set up on an open site not far from the Observatory. It is contemplated that when preliminary observations have been carried through, provision will be made for continuous records of the air-earth current and of variations of short period in the electric field.

Daily photographs (glass negatives) taken with the photoheliograph have been received from Dehra Dûn. These are stored at the Science Museum, South Kensington. Positive prints on paper are also received from Dehra Dûn, to be mounted on cartridge paper and bound up in yearly volumes. To fill gaps in the series, prints from the Greenwich and Cape plates are available. Enlargements of spectroheliograms are mounted alongside these prints for comparison.

In accordance with the arrangement made with the Indian Government, 331 spectroheliograms showing the disc in K light have been received from the Kodaikánal Observatory for the period 1912 October 1 to 1913 September 30.

Lectures have been given by Professor Newall on Solar Research and by Mr. Stratton on Stellar Physics.

Dunsink Observatory.
(*Director, Professor H. C. Plummer, Royal Astronomer of Ireland.*)

The staff consists, as at the close of the preceding year, of the Director and Mr. C. Martin, Assistant. The Pistor and Martins meridian circle has been used for the determination of time only, and the time service to Dublin has been continued as in previous years. The South Equatorial has been used to show objects of interest to visitors on the first Saturday of each of the winter months.

The principal observing work has been done with the Roberts photographic reflector. In spite of very bad weather conditions, particularly in the latter half of the year, a total of 282 plates has been secured. These have been chiefly devoted to the observation of short-period variables. The light curves of SU and SW Draconis have been communicated to the Society, and a general study has been given to their type of variation.

As mentioned in the previous report, the Director has continued his discussion of the systematic motions of the stars of Type I., based on the radial motions chiefly determined at the Lick Observatory and at Santiago (Chile). The results have been communicated to the Society in three papers. The Director also gave a course of lectures on quaternions in the Michaelmas term.

Durham University Observatory.
(*Director, Major E. H. Hills, C.M.G., D.Sc., F.R.S.*
Observer, F. C. H. Carpenter, Esq., B.Sc.)

The early part of the year was devoted to observations with the almucantar. A paper on the results obtained was presented to the Society and printed in *M.N.*, vol. lxxiii. p. 369. In order to elucidate further the puzzling changes of zenith often found during a night's observations, a sensitive level, on a mounting designed so that it can be reversed without any change of balance, has been constructed by Messrs. Cooke and fixed on the float of the almucantar. This level is arranged so that it can be read at the same time as the star observations are taken. The preliminary adjustments are now complete and observations are being made.

The Director has designed a new zenith photographic telescope on the suspension principle, with a Cooke triplet photo-objective of 8 inches aperture, and about 56 inches focal length.

The Board of Curators has approved of the requisite expenditure, and this instrument is now being constructed by Messrs. Cooke. A full description of it will be presented to the Society at an early date. Regular meteorological observations have been carried out as in previous years. Lectures on optics and astronomy have been delivered by the observer.

The Astronomer Royal has joined the Board of Curators.

Glasgow Observatory.
(Director, Professor L. Becker.)

At the end of March 1913 the Meteorological Committee of the Royal Society withdrew its annual grant on the ground that "the purpose which the Committee had in view in establishing in 1868 a meteorological observatory of the Kew type at Glasgow may now be regarded as partially fulfilled and to be realised in other ways."

In consequence of this reduction in the income of the Observatory, the services of the second assistant were dispensed with on April 1, and the two photographic recording instruments, viz. the barograph and thermograph, were dismantled after having been uninterruptedly in operation for forty-five years. Otherwise the Meteorological work has been continued as in former years, and the reductions have been kept up to date.

Liverpool Observatory. *(Director, Mr. W. E. Plummer.)*

The Post Office authorities having granted a licence for the erection of apparatus to receive messages by wireless telegraphy, the necessary arrangements have been completed under the superintendence of Mr J. J. Shaw of West Bromwich. The aerial is carried from the roof of the anemometer house to a flagstaff, 180 feet distant, and has a mean height of 80 feet above the ground. The form of detector employed is electrolytic, and is designed to work with direct or loose coupling. The proximity of the Government station at Seaforth, equipped with very powerful apparatus, has necessitated particular care in the "loose couple," but the devices adopted effectively prevent "jamming." In addition to the morning and night signals from Norddeich and the Eiffel Tower, the French series of signals in connection with the Longitude determination with Washington are also recorded. The Arlington signals have not been detected. The West Longitude of the Observatory, which was increased in 1894 to $12^m17^s{\cdot}33$, seems to require a still further positive correction of $0^s{\cdot}17$.

The routine work of the Observatory proceeds as explained in earlier reports. The meteorological observations, the testing of scientific apparatus, and the distribution of time-signals have been continued without interruption. An attempt has recently been made to connect the meteorological observations more closely with tidal variations, with the view of reducing the discrepancies between observation and prediction. The ultimate aim is to forecast a correction to the computed times and heights.

The Equatorial has been used for extra meridional observations as in former years.

Radcliffe Observatory, Oxford.
(*Director, Dr. Rambaut, Radcliffe Observer.*)

During the year 1913 the 24-inch refractor has been employed as in recent years in photographing certain selected areas for determining the proper motions of the stars contained in them down to the 14th magnitude.

The weather has been even more unfavourable for astronomical photography at Oxford than during 1912, and the year has been marked throughout by an unusual amount of cloud. The condition of the atmosphere has seriously retarded the progress of this work, in which two exposures of half an hour each in a clear sky, free from strong moonlight, are necessary for each plate, and in spite of the sustained zeal of the observers the result for the year is unfortunately rather meagre.

In connection with the proper motion scheme only 30 plates have been obtained, and, of these, 4 were incomplete, leaving only 26 which are considered satisfactory for the purpose immediately in hand. During the year 12 plates have been packed up and stored in air-tight boxes, and 12 more are now ready to be packed.

One other plate (37B), representing the region surrounding B.D. $+41^{\circ}750$ (or Σ443), which had been originally exposed as a parallax plate in January 1905 but never completed, was, after eight years' storage, again exposed on 1913 February 4 and treated as a proper motion plate. It thus afforded an indication of the degree of accuracy to be expected from the plates which are now being stored at this Observatory year by year. The results obtained from this plate have been communicated to the Society and published in the *Monthly Notices*, lxxiii. 8. Here it need only be stated that they appear eminently satisfactory. The plate, though kept with less care than those which are now being put away (having been merely stored in an unsealed light-tight tin case and wrapped in paper), seems to have suffered very little indeed, whilst the probable error of the annual proper motion deduced is shown not to exceed $\pm 0''{\cdot}01$ in either co-ordinate.

Towards the end of September it was discovered that something was wrong with the large triple roller which supports the greater part of the weight of the telescope and relieves the pressure on the upper bearings of the polar axis. On dismounting the roller-frame it was found that the axle of one of the three wheels which compose the roller was snapped across and that the pivots of the other two wheels and the bearings in which they fit were very much torn by broken fragments. The whole apparatus was sent to the maker for repair, but, owing to the strike in Dublin, it was much delayed on the road and did not reach Sir Howard Grubb's workshop till more than three weeks had elapsed. The apparatus, thoroughly repaired, and improved by the substitution of ball-bearings for cylindrical roller-bearings, was received from Sir

Howard Grubb on November 12, and has been working very satisfactorily ever since.

This accident necessitated a readjustment of the polar axis of the instrument, which was effected by means of observations made on November 18 and 22.

The 10-inch Barclay equatorial has been employed for miscellaneous observations, including observations of the nebula N.G.C. 7006, and Westphal's comet (*d* 1913). This comet, which, as will be remembered, became unexpectedly faint and had, as Professor Barnard said, "simply gone to pieces" before reaching perihelion, was seen by the Oxford observers on October 23 and 27; but early in November it could not be found with the same instrument.

This telescope has been employed by Mr. Barrett as in former years for observing certain variable stars. His list includes RW and ST Draconis; VV Aurigae (=17, 1912); 4, 1913 Tauri; 5, 1913 Arietis, and others. Of these he has made 956 comparisons spread over 32 nights. The variability of the last two was noted by Mr. Barrett in the course of his study of the parallax plates, and was announced in the *Astronomische Nachrichten*, No. 4640.

Very satisfactory progress has been made during the year in the measurement and reduction of the parallax plates taken in recent years with the 24-inch refractor. In all 73,976 measures on 15 of these plates have been made, to which must be added 13,642 measures on the proper motion plate 37B, and 2540 measures for determining the errors of the microscope screw, amounting altogether to 90,158 measures of photographs made with this instrument during the year. Of the 15 plates, 9 were taken on Professor Kapteyn's plan, pure and simple, while 6 of them form 3 pairs of "split triples."

The measures on 12 out of the 15 plates have been completely reduced, the parallaxes determined, and the results carried into the card-catalogue as a preliminary step towards preparing them for the press. One of the 3 remaining plates is in the course of reduction.

The card-catalogue now contains, in addition to those enumerated in last year's report, 456 separate determinations, deduced from 5 plates, of the parallaxes of 305 * stars in the region of B.D. +51° 1094, and 696 separate results for 369 stars surrounding B.D. +40°1758, deduced from 2 Kapteyn plates and 3 pairs of "split triples," making in all 1152 separate determinations and 420 stars added during the year. If these figures are added to those given last year, it is found that in all 3642 separate determinations for 1608 stars are now contained in the card-catalogue. To these have still to be added 192 single determinations made at Oxford, and 183 determinations of the parallaxes of 75 stars deduced from the Oxford plates by Professor Kapteyn (as described in last year's report), making a total of 4017 separate

* Of these stars 254 were included amongst those mentioned in last year's report, leaving only 51 added this year.

determinations of the parallaxes of 1875 stars now awaiting publication.

Early in the year vol. li., part ii. of the *Radcliffe Observations*, containing the results of meteorological observations made at this observatory during the year 1912, was printed, and a limited number of copies distributed to meteorological observers and others who had expressed a wish to have the separate parts as they appeared. Part iii. of the same volume, covering the year 1913, is now in the printer's hands. The volume when complete will include the results for the five years 1911–1915.

University Observatory, Oxford.
(Director, Professor H. H. Turner.)

The first part of volume viii. of the *Astrographic Catalogue* is printed, and will shortly be distributed. As stated in the last report, it gives mean corrections to the meridian places of the Cambridge Catalogue, with a discussion of the magnitude equation of these meridian observations and its changes from year to year. In this discussion the epoch of the Cambridge observations is the mean date of several observations, which may have been made in widely different years, and the changes from year to year are thus somewhat masked. But to go behind this mean date would have involved great labour, even if the separate dates had been readily accessible, which is not yet the case; and the above compendious discussion served the purpose of showing that without constant re-investigation of the magnitude equation, visual observations of stars fainter than the ninth magnitude are subject to considerable systematic errors. The continued observation of these faint stars by visual methods involves therefore great labour if the necessary accuracy is to be attained, while photographic methods are easy and accurate. The decision taken by the Permanent Committee to reobserve all the reference stars by visual methods is thus open to grave objections. In some parts of the sky visual work can no doubt be restricted to stars brighter than 9·0 mag., but near the poles of the Galaxy there are not enough of these to give good constants of the plates. If we must in any case observe stars fainter than 9·0 for some parts of the sky, a method which is unsuitable generally is at a disadvantage with one capable of general use. Hence it is urged that some photographic method of observing the reference stars should be studied forthwith, without spending further labour and time on the visual method.

The plan advocated at this Observatory has already been published. To show the success attained, it was necessary to have some fairly accurate standard of comparison; and this has now been obtained by the above preliminary investigation. The main work of photographic reobservation has now been resumed.

The reductions for the Vatican plates, undertaken at this Observatory, have gone on steadily. Zone $+64^{\circ}$ was completed

last year, and is now being printed, sheets up to $9^h\ 54^m$ being in type. Zone $+63°$ is fully reduced, and $+62°$ all but 2 or 3 plates. The residuals are being entered in ledgers as they are obtained. Places kindly furnished by the Astronomer Royal were available for comparison with the upper half of zone $+64°$; and for subsequent zones the upper half of each can be compared with the lower half of the preceding. In this way a number of errors have been detected in time to correct them before printing. Places for 1900·0 have been entered for all stars: residuals for zones $+64°$ and $+63°$ are entered, and 0^h–15^h of zone $+62°$. Funds for the actual computing are now being supplied by the Vatican Observatory, but much work of general superintendence falls on the staff of this Observatory.

The harmonic analysis investigations were diverted about a year ago by the appearance of a similarity between the variations of S Persei and those of Sun-spots; and a paper on the latter by Mr. Kimura led to a detailed study of the Sun-spot periodogram. A new departure of analysis in Fourier sequence was taken; and ultimately the series was tested for discontinuity, with results laid before the Society in December. The outcome is briefly a suggestion that collisions between the planet Saturn and the swarm of meteors manifested (in part) to us as the Leonids leave a number of meteors reduced nearly to rest after the collision. These fall towards the Sun, forming a subsidiary swarm revolving round him, with grazing incidence at perihelion, in about eleven years; and portions of this swarm continually falling into the Sun cause the Sun-spots. The orbital revolution of this subsidiary swarm is continually being perturbed by the main swarm, whence arise the irregularities in the 11-year period. The whole of this investigation involved much labour, and it may be regarded as the chief work of the year.

The death of Mr. S. A. Saunder put in the hands of the Director his work relating to a standard Lunar Nomenclature. Under Mr. Saunder's direction Miss M. A. Blagg had collected a list of names of lunar formations from the maps of Beer and Mädler, Schmidt, and Neison. On consideration it was determined that this should be printed, as a necessary preliminary to the work of the International Committee on Lunar Nomenclature. It has been passed through the press by Miss Blagg, and a copy was presented to the Society in January. The funds for printing were courteously defrayed by the French Academy.

Since the death of Professor John Milne, on July 31, the Director has provisionally undertaken the superintendence of the seismological work at Shide.

The Director attended the meeting of the International Union for Solar Research at Bonn in August last, and presented the report of the Computing Bureau.

Mr. R. S. Capon, B.A., of St. John's College, has been appointed second assistant for one year.

Mr. R. J. Pocock, B.A., of Queen's College, who has worked as

a research student at the Observatory has been appointed Director of the Nizamiah Observatory, Hyderabad.

Mr. A. E. Young, formerly Deputy Surveyor General of the Federated Malay States, has been working for some months at the Observatory as a volunteer.

Mr. J. D. McNeile of Wellington College has kindly measured several repeated plates with a micrometer lent to him by the Observatory, and has in this way detected a number of proper motions of faint stars. An interesting result emerging from this work is that an interval of about 10 or 12 years yields very few proper motions, but with an interval of 17 or 18 years there are several on each plate.

A receiving apparatus for wireless time-signals has been erected by Mr. Capon, and is a great convenience.

The Coats Observatory, Paisley.
(*Convener, Mr. John Woodrow.*)

During the past year extensive renovations have been carried out at the expense of Sir Thomas Glen-Coats, Bart. The meteorological and seismological work has, however, been carried on as usual, and the reports sent to the various headquarters.

All the instruments, including the equatorial telescopes, have been overhauled by their various makers.

The new Dines-Baxendell anemograph was severely tested by the winter's storms, but is giving entire satisfaction.

A Beckley self-recording rain-gauge—of the float pattern—designed by Messrs. Hicks of London and adopted by the Meteorological Office at its principal stations, has been fitted up, and promises to do well.

A new controlled clock, showing Greenwich mean time, has been set up in the entrance-hall.

Temple Observatory, Rugby. (*Director, Mr. G. M. Seabroke.*)

The usual course of instruction to members of the School has been followed during the past year. Boys are allowed to take up any special subject such as Transit observations, Double Stars, etc. Mr. Hewlett has continued the measurement of a few doubles in his spare time.

Royal College of Science, South Kensington.
(*Assistant Professor, A. Fowler, F.R.S.*)

The instruments were chiefly used for the instruction of students, but spectroscopic observations of the sun were continued as opportunities occurred.

In the laboratory an investigation of the spectrum of magnesium

resulted in showing that the well-known spark line 4481·3 belongs to a series of which seven additional members were identified. The triplet series of magnesium lines was also considerably extended, and four additional lines of the "Rydberg" series were identified with strong lines of the solar spectrum of previously unknown origin (*Roy. Soc. Proc.*, A, vol. lxxxix. pp. 133, 137). A new band spectrum, apparently due to helium, was investigated by Mr. Curtis, but this has not yet been traced in the spectrum of any celestial body (*Roy. Soc. Proc.*, A, vol. lxxxix. p. 146). The spectra of titanium and silicon chlorides, as developed by active nitrogen, were investigated by Mr. Jevons, who discovered a new spectrum of bands which is attributed to silicon nitride (*Roy. Soc. Proc.*, vol. lxxxix. p. 187). A band spectrum, probably due to carbon monosulphide, was discovered by Mr. Martin, research student, but the characteristic bands are too far in the ultra-violet to have any astrophysical application (*Roy. Soc. Proc.*, A, vol. lxxxix. p. 127). Another research student, Mr. Cowell, was occupied with measurements of the red bands of the Swan spectrum of carbon, for use in the interpretation of the spectra of comets.

A report on observations of Sun-spot spectra was presented to the International Union for Solar Research at the Bonn meeting.

Hill Observatory, Salcombe Regis, S. Devon.
(*Director, Sir Norman Lockyer, K.C.B., F.R.S.*).

The Observatory is still in course of erection, and the main work since April last has been the arrangement of the internal fittings of the finished buildings and the erection of some of the observing instruments and their houses.

The buildings at present completed are: (*a*) a porter's lodge; (*b*) laboratory (104 × 21 feet) divided into computing-room, spectroscopic room, Director's room, photographic room, and workshop; (*c*) power-house (40 × 15 feet); (*d*) 21-inch siderostat and 9-inch prismatic camera; (*e*) Rusthall dome and annexe; (*f*) store-room (30 × 20 feet). A receiving wireless station has been in operation since July 3.

The observing work consisted in the first instance in securing photographs of spectra of some of the brighter stars with the 9-inch prismatic camera (prism 45° angle) in conjunction with a 21-inch siderostat. On the completion of the erection of the Rusthall twin refractor, consisting of 10- and 12-inch objectives, the latter having a 12-inch prism of 20° angle in front of it, work was commenced with the adjustments and the securing of photographs of stellar spectra. Thirty-eight spectra, including four of the great nebula in Orion, have been obtained.

No experimental laboratory work has yet been commenced, but a spectroscope of the Littrow form with a grating has been erected in the spectroscopic room, and a 12-inch siderostat is placed outside

the building with a secondary mirror to be used in conjunction with it.

Other buildings and instruments are in course of erection.

The researches at present are confined to stellar classification.

Stonyhurst College Observatory.
(*Director, Rev. W. Sidgreaves, S.J.*)

In 1913 the solar surface was observed on 200 days, and 44 drawings have been made. Of these there are 25 showing spots and faculæ, and 19 showing faculæ only; or, omitting the faculæ, we have the record number of 175, or 87·5 per cent. of the observing days, on which the surface was seen to be free from spots.

The high latitude group of small spots observed on February 19 failed as a forerunner of returning solar activity. It was followed by seven months of solar calm, broken only by three small spots of 0·1 magnitude (unit 1/5000), of one day's duration, on April 7, July 30, and August 23. And this period has been, without doubt, the calmest in our history of the solar surface. The small spot seen on August 23 was in south latitude 23°; and since then other high latitude spots have been recorded on six days—two in October, one in November, and three in December. One of these, on December 29, was in south latitude 41°.

Cloudy weather has been very greatly against progress with our solar and stellar spectrographs. No Sun-spots within the reach of the grating spectrometer have been observed; and the instrument has been employed only for comparative photographs of the red-end spectra of the Sun's centre and limbs.

Clear, moonless nights have seldom lasted long enough for satisfactory spectroscopic exposures on nebulæ. But 6 plates of the spectrum of Nova 2 Geminorum were obtained with the Whitelow camera between February 27 and April 5.

The Observatory has been recently provided with a very efficient radio-telegraphic receiver, including a Brown's relay, of his improved "W type." And it is impossible to speak too highly of its sensitivity and general behaviour. With it we may expect to obtain the correction to our longitude as closely as our transit instrument can give us our local time. For, with the telephones resting on the table, the coincident beats of the chronometer with those of the Paris time-vernier signals are more easily pointed than with the telephones on the ears.

In preparation for these observations, all the fair nights of the summer and autumn have been devoted to the transit instrument and its clock.

The meteorological automatic instruments of the Meteorological Office have been in full work throughout the year, and our Milne seismograph has always worked well. The annual mean monthly displacements of the boom, for the past three years, show a steady decrease of seismic disturbance, expressed by the figures: 1911, 0·50; 1912, 0·27; 1913, 0·14.

Wolsingham Observatory (Rev. T. E. Espin).

The micrometrical measures have been continued through the year, also the examination of the stars in the selected zones. The results have been communicated to the Society. During the summer the Observatory has been rebuilt, and the dome raised to make room for the 24-inch reflector, now in process of construction. It is hoped that the survey of the last section of zones $+45^\circ$ to $+55^\circ$ will be completed before the present telescope is dismounted. At the end of 1913 the work in the zones $+48^\circ$ to $+54^\circ$ had been completed, and of the remainder from 8 hours to 24 hours was also finished.

Mr. C. R. D'Esterre's Observatory, Tatsfield, Surrey.

The instrumental equipment remains the same as in previous years, but many improvements in details have been made. In the reflector a new 15-inch mirror and $3\frac{1}{2}$-inch minor axis diagonal made by G. Calver are now normally in use in place of the old 15-inch and $3\frac{1}{4}$-inch diagonal. Thanks to the perfection of the new mirrors, the efficiency of the instrument has been very greatly improved. From experience on a large number of variable star fields it was formerly the practice to give an exposure of 30 minutes in order to record good printable images of stars at the visual limit of the 15-inch; the focal ratio of the old mirror is F 4·95. The new 15-inch works at F 4·85; an exposure of 10 minutes on the same brands of plates now more than suffices to penetrate to the 30-minute limit specified above. Also it was the practice to cover the fields of new variables at least twice with exposures of 1 hour, in order to discover any very faint stars in the immediate neighbourhood of the variables; all these objects are now satisfactorily recorded with exposures of 15 minutes under good average conditions. The reflector can also be relied upon to record symmetrical star images over a field of at least 30′ of arc diameter, and they are quite good over a diameter of 60′; it is exceptional for a negative to fail to enlarge with advantage to 16 diameters. With exposure up to 2 hours the printed images of the faintest stars do not exceed $2''$ of arc diameter = 0·0007-inch diameter at the focal plane. Visually also the performance is extremely satisfactory: under good conditions star "31" of the Harvard North Polar sequence (*A.N.*, 4600), vis. mag. about 16·1, can be just held steady with power 360, and stars around $9^{m}\cdot0$ give minute dots surrounded by two close diffraction rings centred in a very faint disc of outstanding light, due apparently entirely to the eyepiece employed.

During the year some photographic records have been obtained on 121 nights, but the observing conditions have been, as a rule, of indifferent quality. The total number of exposures made is 684:

of these 484 plates were obtained with the portrait-lens cameras, average exposure 26·6 minutes; and 200 with the reflector, average exposure 29·3 minutes. Excluding 122 exposures on the region of the North Pole made for magnitude determination, the work has been concentrated on the same selected regions in and near the Milky Way as have been under observation during previous years. Of these regions twenty are now covered by over eleven hundred plates, and may be said to be under regular observation. Experience shows that it is advisable to restrict the number of large areas and increase the frequency of the observations. The duplication of the portrait-lens exposures increases the value of the records very greatly, and appears to be absolutely essential in order to establish satisfactorily the conditions obtaining on any given night.

The new variable stars, 2, 6, 7, 8, 9, 11, 18, 22, and 26, 1913, have been discovered and announced in *A.N.*, 4632, 4640, 4648, 4670, 4676, 4697. There are also seven other new objects now under observation, but not yet announced. It is now the practice to give the magnitudes of the comparison stars and range of variation on the Harvard scale at the time of announcement, and, thanks to the large number of observations of each region, it is generally possible to say something definite about the period and character of the variation.

The work of following up all the new objects hitherto discovered is also well in hand, and at least three pairs of plates on each region and the North Pole are being obtained in order to place the magnitude data on a reliable footing.

The programme of work is now in its third year of productiveness, and the following are some of the conclusions which are definitely coming into prominence:—

(1) The proportionate rarity of objects varying one magnitude or more amongst the faint stars. It is probable that the ratio is decidedly less than 1 in 5000 for stars below $10^{m}\cdot0$.

(2) The non-appearance of any object of faint maximum which can be definitely stated to be a nova. The area under close observation is nearly 1000 square degrees, situated for the most part in and near the Milky Way: the plates are all gone over very carefully in pairs with a lens magnifying 5 diameters, and details examined with 16 diameters: from the faintness of most of the variables discovered, it appears reasonable to assume that a faint nova would not be missed. The data are sufficient to justify the suggestion that there is no such phenomenon as a nova whose characteristic maximum is as low as $12^{m}\cdot0$. The inference suggested is that our stellar universe is so limited in extension that the minimum outburst characteristic of a nova shines for us at maximum as a relatively bright star. This fits in well with the possibility that our stellar system may be an isolated group of bodies similar to the Andromeda and some other spiral nebulæ.

(3) The non-disappearance at minimum of any of the faint variables so far discovered: the faintest minimum recorded is $18^{m}\cdot0$

for 2,1913 Cassiopeiæ. This, again, strongly favours a limited stellar universe.

(4) Most of these faint variables are considerably brighter visually than photographically near maximum; this difference tends to increase for some weeks after maximum, but as minimum is approached the photo and visual magnitudes tend to become equal. Frequently near minimum the variable sinks to approximately the same magnitude as a companion star which does not vary. This suggests that the variables spring from a very distant layer of stars, and that they are not faint because of their colour. Maximum appears to be the abnormal event in their history.

(5) Amongst the numerous series of comparison stars now in use it is rare to find the visual order of magnitude differing from the photographic order below $14^{m}\cdot0$. It is also rare to find photographic pairs of 5″ or under amongst stars below this magnitude.

Mr. G. J. Newbegin's Observatory, Lyndale, Sutton.

In 1913 observations for solar prominences were made on 61 days: 25 of these yielded 36 prominences, and the remaining 36 none; a mean daily average of 0·59 results therefrom.

By dividing the year into two equal parts, the first half gave 15 prominences for 31 days, and the second half 21 prominences for 30 days. The quality of the prominences was much the same as in 1912, both in absence of brilliancy and elevation.

Two small spots appeared in December about the middle and end of the month, the latter being crossed by faculæ.

The two spots and more prominences in second half of year may indicate activity as having again commenced.

Prominences recorded as bright	. .	11	= 36
,, ,, faint	. .	25	
,, ,, on S. hemisphere		18	= 36
,, ,, ,, N. ,,	.	18	
,, ,, ,, W. limb	. .	21	= 36
,, ,, ,, E. ,,	. .	15	

Rousdon Observatory, Devon.
(*Sir Wilfrid Peel's, Mr. C. Grover, Observer in charge.*)

The building, which was erected thirty years ago, is kept in good repair, and the instruments are in perfect working order. Weather has been fairly favourable, and observations were made on 114 nights. October was the finest observing month of the year. Observations of the long-period variable stars were continued exactly as in former years, and 306 magnitudes were recorded, making a total of 12,075 magnitudes during the twenty-eight years this work has been in progress. The instrument in use throughout is the 6·4-inch Merz refractor equatorial, which shows stars down to 13·0 magnitude.

Observations with the transit instrument are frequently taken for the regulation of the sidereal clock, which maintains a very steady rate. The usual meteorological observations have also been regularly continued.

The Rev. T. E. R. Phillips's Observatory, Ashtead, Surrey.

During 1913 observations were made of the surface features of the planets Jupiter, Saturn, and Mars with the 12¼-inch Calver reflector and the Coleman 8-inch Cooke refractor kindly lent by the Council of the Society. The planet Jupiter, despite its low position in the sky, presented features of quite unusual interest in the outbreak of dark and light spots along the south border of the north equatorial belt, and in the rapid motion they exhibited. A large number of transit observations of these objects shows that the velocity of at least the north part of the equatorial current has recently become so accelerated that it is now practically what it was thirty years ago. A short summary and discussion of the observations has been communicated to the Society.

Systematic comparisons with neighbouring stars are also being made in conjunction with observers elsewhere of Saturn's Satellite Iapetus, with a view to the investigation of its variation of brightness.

A number of double stars have been measured during the year with the 8-inch refractor.

Mr. J. H. Reynolds' Observatory, Harborne, near Birmingham.

During the year an apparatus was devised and constructed for use with the 28-inch reflector to enable the photographic plate to be placed in the centre of the reflector tube in the primary focus, and at the same time to bring the image of the object to be photographed, and also the rays from a suitable guiding star, to the side of the tube for visual examination. This was done by means of two small plane mirrors placed at an angle of 45° and two collimating lenses of 7-inch focal length placed behind the focal plane, thus bringing a cylinder of parallel rays to the side of the tube, which were then converged again to a focus by two small telescopes. The finding telescope, mirror, and lens, were fixed in position, while in the case of the following apparatus the mirror and lens were on a slide capable of movement in R.A. for finding a suitable guiding star, the telescope being provided with illuminated double cross wires. Although this arrangement possesses some distinct advantages optically over the usual Newtonian form, it has the great disadvantage of a restricted field in the finding telescope, which makes small faint objects difficult to find, and the impossibility of getting perfect achromatism and a flat field with lenses of the usual type is against good definition for visual work. On the whole, the balance is in favour of the ordinary Newtonian form.

An addition of considerable value for work on photographs of nebulæ has been a photomicrometer of the Hartmann type. This enables the density of various portions of a nebular negative to be measured and compared with a calibration curve which gives the equivalent light intensities. The provision of a micrometer stage for the negative also permits of the instrument being used for measuring positions. A contour map in light intensities of the Orion nebula, based on a series of photographs with graduated exposures taken by the writer with the 30-inch reflector of the Helwân Observatory, has been undertaken.

Khedivial Observatory, Helwân.
(Superintendent, Mr. H. Knox Shaw.)
[*The Observatory is attached to the Physical Service of the Survey Department: Director, Mr. B. F. E. Keeling.*]

Time-Service.—The time-service has been maintained as usual. The Standard Riefler clock stopped twice during the year: on the former occasion owing to corrosion of the winding contact; on the latter the trouble was of a more serious nature, and at the end of the year its cause had not been found. Mr. T. L. Eckersley has fitted up a wireless telegraphy receiving apparatus, and the night time-signals from the Eiffel Tower are picked up without any difficulty. The day signals are, however, quite inaudible. Transits were taken for the purpose of the time-service on 68 nights.

Reynolds Reflector.—The telescope was used on 137 nights, and 171 plates were exposed during the year:—

81	plates	on	62 nebulæ
23	,,	,,	J VIII
1	,,	,,	Comet 1913*a*
9	,,	,,	,, 1913*b*
17	,,	,,	,, 1913*c*
6	,,	,,	,, 1913*e*
1	,,	,,	,, 1913*f*
11	,,	,,	magnitude fields
14	,,	,,	stars of large proper motion
8	miscellaneous plates.		

In addition, three photographs were taken with the prismatic camera. Mr. Eckersley took the photographs of J VIII in July and August, and a few others. Mr. Reynolds, who stayed at the Observatory for ten days in the spring, took some photographs of nebulæ.

On only thirteen of the J VIII plates have images of the satellite been found which are considered sufficiently good to be measured. Jupiter was at its greatest south declination at this opposition, and the atmospheric conditions were almost uniformly poor during the time that the satellite was under observation.

A series of photographs of stars of large proper motion has been commenced at the suggestion of Dr. E. Hertzsprung with a view to discovering any faint companions they may have.

The occultations of two stars by Jupiter were observed in May.

The new driving worm and sector made by Sir Howard Grubb arrived in January, and tests showed it to be of a high order of accuracy.

Positives of nine nebulæ have been sent to the Society.

Geodesy.—In addition to the usual operations which do not come under the cognisance of the Observatory, the longitude of Khartoum was determined telegraphically in June by Mr. Wade and Mr. Knox Shaw.

Radiation.—Some observations of the solar radiation were made during the autumn by Mr. Eckersley with an Ångström pyrheliometer, and, after consultation with Professor C. G. Abbot, it has been decided to make regular observations with this instrument during the coming year, at times when the Sun's zenith distance is 70° and 50°, and at a third time when it is 35° or as near this as the Sun's declination will allow.

General.—The usual meteorological, seismological, and magnetic observations have been made. Bulletins Nos. 8, 9, and 10 were published during the year.

The Dominion Observatory, Ottawa.
(*Director, Dr. W. F. King, Chief Astronomer.*)

Astrophysics.—Visual observations of double stars with the 15-inch refractor have been continued during the past year, but the principal work, as previously, has been the spectroscopic determination of stellar radial velocities. The stars observed have consisted principally of spectroscopic binaries with a view to the determination of their orbits. Two orbits have been completed during the year, while the observations of several stars, for which, though undoubtedly variable, a period could not be determined, will be shortly published. The decrease in the number of orbits and the abandonment of other stars are due to the fact that the binaries remaining undetermined are those which, owing to the poorness of the lines in the spectra or to the low range of velocity, and frequently to both causes, are difficult and uncertain of determination, and require several times as many plates for satisfactory discussion as those earlier observed.

Consequently considerable time has been spent in experimental work with a view to increasing the efficiency and range of the equipment. More work was done with the grating spectrograph, and also with a half-prism Littrow form. The results, though promising and useful in many special ways, especially in regard to uniformity of intensity over the spectrum and to relatively greater

intensity in the violet, did not show sufficient general advantage over single-prism dispersion to supersede it. But a new prism of baryta light flint has replaced the prism of dense silicate flint in the spectrograph with very marked advantages all along the spectrum, but especially in the violet. At K, a line which is in many spectra the best in the whole length, the exposure required is only one-fourth as great, while with the same exposure six more hydrogen lines are measurable than with the dense prism. In the case of early-type stars this should result in obtaining a greater quantity of observing material in much less time.

Work on the solar rotation with the cœlostat telescope and grating spectrograph has been actively continued. Two series of rotation plates—one in the particular region λ5600, and one in the general region λ4250—have been secured, and also a number of plates at λ5600 with a new reflecting prism device giving a much greater quantity of observing material with the same exposure time. The measures of the 1912 plates show a very close agreement with those of 1911, within one-half of 1 per cent., and the conclusions previously reached have been confirmed.

Considerable time has been spent in the preparation of the specifications and on the design of the 72-inch reflecting telescope, whose construction has been commenced, and which is expected to be completed in 1915. Observations at several places in Canada to determine the most suitable location for such a large instrument are now in progress.

Department of Geophysics.—This branch of the Observatory comprises Seismology, Terrestrial Magnetism, and Gravity. The equipment of the three branches consists of the same instruments as reported last year. Monthly bulletins of the recorded earthquakes are issued as heretofore, and the stations to which the bulletins are sent have been increased to eighty-five, distributed over the world. During the calendar year 95 earthquakes have been recorded, amongst which was a local one, not destructive, felt over an area of 25,000 square miles, and of which a monograph was published. As microseisms have now been clearly associated with areas of low barometer on the ocean, and the consequent waves and disturbed sea, an undagraph has recently been mounted on the Nova Scotian coast, fully exposed to the ocean, for the purpose of correlating the period of the waves with the period of the microseisms. The instrument is as yet not adapted for recording the magnitude of the waves, which is necessary for complete correlation.

A Mainka pendulum, with two components, has been received, and is awaiting installation at Dalhousie University, Halifax. Similarly a specially constructed apparatus has been received for observing the deformation of the Earth by the Moon, and the vault, 23 feet beneath the surface, to receive it here, is in process of building.

The magnetic survey of Canada was continued, and 51 stations were occupied, at each of which the three elements—declination,

inclination, and intensity—were obtained. As before, the stations average about 25 miles apart.

Arrangements have now been made that the gravity work with the half-seconds pendulum, which has been in abeyance for some years, will be resumed during the coming season, and it is the intention to carry it, in time, over the whole of Canada, from the Atlantic to the Pacific.

Meridian Circle.—During the early months of the year the telescope was out of commission for repairs and alterations. In addition to several minor changes, the instrument was thoroughly balanced in every way, in preparation for the undertaking of fundamental observations. During the remainder of the year work was continued on the unfinished list of latitude stars which has been under observation for several years. Owing to continued cloudy weather, and the fact that work was interrupted by the repairs to the telescope, the number of observations, exclusive of broken nights used only for clock correction, was somewhat under 1000 in each co-ordinate. The installation of the azimuth marks has been completed; the focal lengths of the collimating lenses employed are 156 feet and 250 feet respectively; both marks and lenses are arranged for setting vertically over underground marks bolted to the footings of the respective piers; from the preliminary tests which have been made the marks give promise of being satisfactory.

Time-Service.—The time-service has been maintained as heretofore. Besides the dropping of the time-ball on Parliament Hill, recording of time on the seismograph, sending out time-signals, etc., there are in operation somewhat over 300 electrically driven dials in the Government buildings in the city, which are operated by means of several secondary master-clocks continuously synchronised from the Observatory. For the synchronisation of these a new method has been adopted, the chief merit of which lies in the fact that interruptions to the synchronising line can under no circumstances cause the controlled clocks to stop. It was described in the *Journal of the Royal Astronomical Society of Canada*, vol. vii. p. 287.

Field Observations.—During the past summer three observers were engaged in observations for latitude and longitude at various points. The stations occupied included seven in British Columbia (one for latitude only), two in Alberta, and one in Ontario. The base station in longitude for the points in the west was Field, B.C.; one station was also connected with Winnipeg, thus forming a triangle to strengthen the longitude of the base station. Observations for personal equation were made before the work began, and also later in the season. For all points except two, 3-inch Cooke transits with registering micrometers were used, the instruments being adapted for use as zenith telescopes by the addition of latitude levels. For the remaining two points a more portable form of broken-type telescope was employed.

Kodaikánal and Madras Observatories.
(Director, Mr. J. Evershed.)
[*Report communicated by Dr. T. Royds, Acting Director.*]

The Director was on privilege leave from August to November, and from December his services were lent to the New Zealand Government for three months.

Photoheliograph.—Direct photographs of the Sun on a scale of 8 inches to the diameter taken with the 6-inch photo-visual lens from Poona were obtained on 328 days, as against 329 days in 1912.

Spectroheliograph.—Monochromatic photographs of the Sun's disc in "K" light were taken on 325 days, and prominence plates on 300 days. Hα spectroheliograms were obtained on 202 days, but the grating was occasionally removed for use with the spectrograph. Duplicates of the disc plates were sent to the Solar Physics Observatory at South Kensington until its transference to Cambridge, where they are now being sent.

The prominence plates and the Hα plates have been measured as usual, and the results published half-yearly in the Observatory Bulletins.

Grating Spectrograph.—The work with the spectrograph has been mainly along the following lines:—(1) comparison of the centre and the limbs of the Sun; (2) comparison of the centre and the iron arc in air and *in vacuo*; (3) comparison of the limb and the iron arc. These were used to investigate the equatorial velocity of rotation of the Sun, and the study of the displacements of the lines at the Sun's centre and limb. Mr. Evershed has now put forward the view that these displacements can be best explained as an effect due to velocities in the line of sight rather than to pressure, which was hitherto the commonly accepted explanation (see Bulletin xxxvi.). These investigations are being continued, special regard being paid to those lines whose relative effective levels are known, as well as their behaviour under pressure.

A new method of measuring spectrum plates has been worked out by the Director.

6-inch Telescope and Spectroscope.—Visual observations of prominences and spot spectra have been continued with the Hilger solar spectroscope attached to the refractor from Poona. Attention has again been specially given to observation of metallic prominences, of prominences showing displacements, of the appearance on the disc of the D_3 line and reversals of the C line. Their relative frequency on the eastern and western halves of the Sun have been tabulated.

The Kodaikánal data of prominences have been investigated for periodicities, and some light has been thrown on the supposed effect of planets in the distribution of prominences. A comparison of periodicities in spots and prominences was obtained by means of the Catania prominence observations.

Poona 20-inch Reflector.—The new building to accommodate this telescope has not been commenced, as the Government is considering the question of its erection in Kashmir, where the observing conditions at night are better than at Kodaikánal.

Publications.—Bulletins Nos. xxvii. to xxxiii. were published and distributed during the year, and Nos. xxxiv. to xxxvi. were already in the press at the end of the year. Two papers were contributed to the *Monthly Notices*. Two communications by Mr. Evershed were read at the International Solar Union Conference at Bonn in August.

The meteorological observations were continued as usual, but the reductions and tabulations are now carried out at the Meteorological Offices at Simla and Madras. The Milne seismograph worked satisfactorily throughout the year.

At Madras the astronomical work was confined to the maintenance of the time service.

Adelaide Observatory, South Australia.
(*Director, Mr. G. F. Dodwell.*)

A list of intermediate stars in the Sydney zone ($-52°$ to $-64°$) was received from Professor Cooke about the middle of the year, and regular observations were commenced early in July on the differential system recommended at the Paris Congress in 1909. The Transit-Circle Telescope was also used for the observation of clock stars for the time-service. The time-ball at the Semaphore was dropped daily at 1 p.m., except on Sundays and a few occasions when telegraphic communication was temporarily suspended. The ordinary system of distributing time-signals throughout the State was continued. A new Riefler Vacuum Case Sidereal Clock of the best quality has been ordered, and it is anticipated that the meridian work will be much improved thereby. Provision was also made during the current financial year for obtaining the equipment for field gravity determination, to be carried on in conjunction with the establishment of a number of latitude and longitude stations in the State. Two stations were occupied for latitude and longitude, viz. — Strathalbyn and Lake Littra (Boundary Obelisk). The Almucantar method, as adapted by Cooke for use with an altazimuth instrument (*M.N.*, vol. lxiii. p. 156), was employed for this work, telegraphic signals being exchanged with the Adelaide Observatory for difference of longitudes. A proposal was received from the International Geodetic Institute for co-operation with La Plata in the latitude variation programme, the two observatories being on the same parallel of latitude within $1'\,8''$. The State Government is willing to allow this work to be undertaken and to grant additional assistance if a suitable zenith telescope is provided from an outside source. It is hoped that this difficulty may be surmounted.

The eight-inch Cooke Equatorial was used for miscellaneous observations, and regular use was also made of it on certain nights

by members of the South Australian Astronomical Society, principally for variable and double star work.

A nine-inch reflecting telescope, made by Mr. David Ross of Melbourne (discoverer of Comets Ross 1883 II. and 1906c) and purchased by the Astronomical Society, has been housed in the Observatory grounds for convenience of use by members of the Society.

The Milne Seismograph has been continuously at work during the year, and the tabulated records have been sent to Shide Observatory, Isle of Wight.

Public visits have been made to the Observatory on practically every Friday evening during the year, and occasional lectures on astronomy have been given at country institutes.

A volume of Jupiter observations and drawings, made principally by the late Mr. E. P. Sells, and including a record of eclipses, occultations, etc., of Jupiter's satellites observed during the years 1876 to 1905, has been published.

Perth Observatory, Western Australia.
(Acting Director, Mr. H. B. Curlewis.)

Meridian Observations.—The preparation of vol. vi. of the Meridian Catalogue, containing the *étoiles de repère* for zones 37° to 39°, was finished during the year and is now awaiting distribution. The publication of this volume completes the meridian work required for the Observatory's share of the Astrographic Survey.

The approval of the list of new "intermediates" prepared for the international meridian scheme has not yet been received from Paris, and consequently it has been impossible to start the observing, although it is doubtful whether a definite beginning would have been possible during the year, owing to the small staff and the stress of other work, which fully engaged their energies. Beyond a few check observations for zone star position, the work on the transit-circle was confined to time observations, 385 clock stars having been observed on 194 nights.

Astrographic Catalogue.—Owing to the necessity of completing the work of the Astrographic Catalogue as soon as possible, the main efforts of the staff have been concentrated upon this undertaking, and Mr. Nossiter, who is in charge of the work, reports as follows:—

"I have the honour to report that during the year 1913 satisfactory progress has been made with the Astrographic work. Some difficulty was experienced in keeping the plates up to date owing to frequent and long spells of cloudy weather. In all, 474 plates were obtained, as follows:—

Catalogue plates	437
Pritchard regions	37

"Of the Catalogue plates 79 were rejected owing to various defects, and the remainder were passed for measurement. Fifty-six

of these plates, completing zones 38°, 39°, and 40°, were sent to the Royal Observatory, Edinburgh, which has undertaken their measurement.

"During the year 53 plates were measured, a total of 18,578 stars being completely measured and prepared for the printer.

"Vols. ii. and iii. of the Catalogue were distributed early in the year, and these two volumes complete zone −32°. Vol. xii., containing 18^h to 24^h in zone −34°, is printed and ready for distribution, and vols. ix. and x. are in the printer's hands. The tables necessary to convert R.A. and Dec. into standard co-ordinates and *vice versâ* were computed for all zones between −32° and −40°, which covers this Observatory's portion of the Astrographic Catalogue. They are now in the printer's hands and will be issued shortly.

"As it was anticipated that it might be of interest to publish the double stars found on the plates during the measurement of zone −32°, I collected and reduced them, and they were published as Bulletin No. I. Further Bulletins will be issued for each zone as it is completed."

Seismological.—The Milne Seismograph registered continuously throughout the year, and a record of all disturbances was forwarded to the Seismological Committee, England, and appeared in the bi-yearly publication.

The Tides.—The predicted tides for 1913 for Fremantle were published, and also the last four months of the year for Port Hedland. This is the first occasion on which tide tables have been issued in Western Australia. During the latter end of the year the tables for 1914 for these two ports were prepared and the printing completed before the close of the year. A few advance copies were forwarded for distribution amongst the shipping firms early in December. This is a work of extreme importance, and it is to be hoped that the Government will continue to make available the funds necessary for its continuance.

The Time Service.—The dissemination of time was carried out as usual. The time ball at Fremantle failed twelve times, due on seven occasions to line-faults and on the other five through omission to hoist the ball. A daily check on the time of ball drop was kept throughout the year, and only ten times did the error exceed a tenth of a second, and never two-tenths. The mean of all the errors approximated very closely to the absolute zero. It is anticipated that before long the Observatory will be connected direct with the Applecross wireless station, so that time signals may be distributed thence to oversea shipping.

Miscellaneous.—The lunar eclipses of March 22 and September 15 were observed and reported to the press. In the case of the latter, it was intended to take photographs for determination of possible lunar atmosphere, according to a programme suggested by the Royal Observatory of Belgium. Unfortunately, before the moon was half eclipsed dense clouds completely obscured it and it was invisible till some time after the eclipse was over.

Observations of Gale's and Westphal's comets were made when the weather and freedom from other work permitted.

The interest taken by the general public showed no sign of abatement, rather the reverse, for over 1000 people visited the institution on 97 evenings during the year.

The starting of an Astronomical Society, with its headquarters at the Observatory, marks a distinct epoch in the scientific history of the State, and it is anticipated that encouragement and development of amateur work will result.

Occasional lectures have also been given, and monthly astronomical information supplied to the press, including tables of rising and setting of Sun and Moon, and times of high and low water.

Sydney Observatory.
(*Director, Mr. W. E. Cooke, Government Astronomer.*)

The reorganisation of the Observatory and transference to a more suitable site has been postponed from time to time, and so the work during 1913 has been mostly of a local character.

Efforts have been made to improve the public time service of the metropolitan district, and at the close of the year the Federal Postmaster-General gave his consent to a scheme which, it is hoped, will prove beneficial to the public. As soon as this is in operation any telephone subscriber will be able, on demand at any moment, to obtain correct standard time. Those who want it merely to the nearest half-minute will be placed in communication with an operator who is stationed in front of a clock controlled from the Observatory: whilst those who require fractions of a second will receive the seconds-beats of the standard time clock at the Observatory.

An effort has also been made to establish wireless time signals, similar to those in operation in Europe and America, for the benefit of navigators and people living in districts remote from public clocks or telephones. Up to date, the Federal authorities have given no reply to communications on this matter.

Several comets have appeared, and observations taken where possible.

Some of the results of transit work in previous years have been tabulated for comparison with modern catalogues, and the analysis has not been sufficiently satisfactory to warrant their publication.

A course of lectures on elementary astronomy has been given at the University, and an examination on the subject appears for the first time in the calendar.

An extension course of three lectures was also delivered at the country centres, Bathurst, Blayney, Orange, Dubbo, and Gilgandra.

Considerable attention has been devoted to the popular aspect of astronomy. The Observatory has been open, as usual, to any visitors who call on Monday afternoons; and in addition receptions have been held two or three evenings every week. For

these latter, owing to lack of accommodation, each party is necessarily limited in number, and engagements must be made and booked in advance. In addition to the usual instruments, an electric lantern has been installed, with a selection of good slides, and this is frequently used, either to illustrate points that require elucidation, or to show objects of interest not suitably placed for telescopic observation. These semi-educational evenings are becoming very popular, and our available time is now invariably booked for a month or two in advance.

A fair amount of experimental work, both in workshop and office, has been done in anticipation of the coming reorganisation. Working catalogues and computation tables are being prepared in the office, and models of new instrumental designs are being made by the mechanical department.

In conclusion, it must be once more placed on record that permanent work of real scientific utility, suitable for such an institution as this, is not possible under present circumstances. The year, however, has not been altogether wasted, and present indications for an immediate commencement of the much-needed reorganisation are decidedly hopeful.

Union Observatory, Johannesburg.
(*Director, Mr. R. T. A. Innes, Union Astronomer.*)

Instrumental Equipment.—This has been increased by the arrival of a twin 6-inch and 7-inch refracting telescope carrying a transferable camera-end and a 6-inch object-glass prism, the whole equipment having been presented to the Observatory by the late Mr. J. Franklin-Adams. A building for the use of this instrument is now in the course of erection. The disks for the 26-inch refractor have not yet been delivered to Sir Howard Grubb, but Messrs. Chance Bros. hope to have them ready immediately, so that there is some prospect that the telescope may be in commission in 1914.

9-inch Refractor.—Measurements of double stars have been continued and completed. Measurements of upwards of 540 pairs (at least two nights' observations on opposite sides of the meridian) were secured; of these 118 are under 1″ in distance; incidentally 13 new pairs were recorded. Several interesting cases of binary motion have been noted, and others have been confirmed: thus β 738, α Fornacis, and I 390 are at present single; Brisbane 3574 turns out to be a binary of unusual character; I 83 shows an increase of 39°·5 in angle in 16 years; I 221 a decrease of 28° in the same period; Sellors 19 an increase of 32° in 18 years; λ 238 of 31° in 16 years; and Russell 321 a decrease of 26° or more in 33 years; besides these there are several pairs showing large changes, but with which a 9-inch telescope is not powerful enough to deal with certainty. Measures of nearly every southern pair in motion have been secured.

The phenomena of Jupiter's Galilean satellites have been observed on the same lines as before.

Comets 1913 *e* (Zinner) and 1913 *f* (Delavan) were followed as long as possible.

$2\frac{5}{8}$*-inch Talcott Telescope.*—Latitude and time observations have been maintained, but latitude observations are now limited to three nights a week, so that the winter series (cloudless nights) will not greatly outnumber the summer series (frequent cloudy nights).

Franklin-Adams Star-Camera.—The exposures made covered 99 hours, and were almost entirely limited to plates for minor planets and comets. The places of 118 minor planets were sent to Dr. Cohn at the Recheninstitut, Berlin. With the 6-inch guiding telescopes many duplicate observations of the phenomena of Jupiter's satellites have been made.

Observatory Circulars.—Nos. 2 to 9 were actually distributed during the year, and Nos. 10 to 12 are in the Government printer's hands. In circulars Nos. 2 and 5 the adoption of a permanent system of reference (called the Galactic System) for the stars and planetary orbits is urged, and in those circulars and Nos. 5, 6, 8, and 9, numerous examples of the simplifications which would result and tables of reduction for 1913 and 1914 are given, whilst in circular No. 10 (1913 November 22) a table for the rapid conversion of right ascension and declination into Galactic co-ordinates is given. The other chief contents of the circulars are:—No. 3, results of the observations of Jupiter's satellites in 1912, and a photograph of the Nkandhla nickel-iron meteorite which was seen to fall; No. 4, measures of double stars in 1912; Nos. 6 and 7, occultations of two stars by Jupiter; No. 8, the proper motion of $-30^{\circ}\,6641 = 0''\cdot83$ towards $163^{\circ}\cdot7$, and on measurements of star photographs by means of projection and simple apparatus; No. 9, a plate showing the variable star 1855, $19^{h}\ 42^{m}\cdot2$, $-16^{\circ}\ 21'$ at two phases. The remaining circulars now in the press will contain: No. 11, observations of Zinner's comet 1913 *e*; No. 12, observations of Jupiter's satellites 1913.

Time-Service, Meteorological and Seismological Observations.—These have been continued unchanged A second mean-time clock, Riefler 286, has been installed.

Staff.—Mr. Innes and Mr. van der Spuy measured double stars with the 9-inch telescope; and Mr. Innes with the 9-inch, and Mr. and Mrs. Wood with the 6-inch, guiding telescopes, observed the phenomena of Jupiter's satellites. Mr. Wood was in charge of the Franklin-Adams star-camera, and Mr. Worssell in charge of the latitude and time observations, many of which were made by Mr. Simpkins. Mr. Wood was on vacation leave until 1913 March 3, and visited several European Observatories; he contributed a paper on South African earthquakes to the American Seismological Society (*Bulletin*, vol. iii., No. 3).

Mr. Innes read a paper on "Cosmogonic Hypotheses" before the South African Association for the Advancement of Science at

Lourenzo Marques, but it has not yet appeared officially: the main argument is that heavy atomic elements cannot be built up by the gravitational condensation of the light atomic elements which exist in nebulæ, and that the chief source of energy in the cosmos is more probably due to the ultimate atomic disintegration under enormous pressure of the heavier elements which are present in meteorites or planetismals.

Lovedale Observatory, South Africa. (*Dr. Alex. W. Roberts'.*)

Observations of variable stars were carried on very irregularly during 1913, only 1800 observations being secured. Almost all the observations were taken to clear up some difficult matter of period, or character of light curve.

The bulk of the work overtaken during the year was the determination of the magnitudes of the comparison stars used as standards of reference. In this determination the Harvard 4-inch photometer was of the very greatest service.

During the photometric survey of comparison stars many evidences of variation were met with. One star in Carina has proved to be a long-period star. Its period and variation have been confirmed at Harvard.

Notes on some Points connected with the Recent Progress of Astronomy.

Discovery of Minor Planets in 1913.

Eighty-eight new planets were discovered or first announced in 1913.

Letter and Number.	Date.	Discoverer or Observatory.
	1906.	
WF_a	Dec. 18	H
WF_b	18	H
WF_c	18	H
	1912.	
RQ	Nov. 5	M
RR	6	M
RS	10	M
RT	30	M
RU	Dec. 7	M
	1913.	
QN	Jan. 7	H
QO 738	7	H
QQ	7	H
QQ^a	Feb. 2	M
QR 739	7	M
QS 740	10	M
QT 741	10	M
QU 742	23	H
QV 743	25	H
QW 744	26	R
QX 745	Mar. 1	H
QY 746	1	H
QZ 747	9	H
RB	12	H
RC	8	S
RD 748	14	S
RE	Apr. 4	H
RF 749	5	S
RG 750	28	P
RH	27	S

Letter and Number.	Date.	Discoverer or Observatory.
	1913.	
RJ	Apr. 28	S
RK 751	28	S
RL 752	30	S
RM 753	30	S
RN	June 6	H
RO	May 31	M
RP	June 13	S
RV	Jan. 9	M
RW	14	M
RX	Feb. 6	M
RY	6	M
RZ	6	M
SA	25	M
SB	25	M
SC	Mar. 7	M
SD	12	M
SE	Apr. 25	M
SF	25	M
SG	3	W
SH	3	W
SJ	Aug. 26	H
SK	26	H
SL	28	H
SM	27	S
SN	Sept. 8	H
SO	8	H
SQ	3	S
SR	3	S
SS	May 9	W
ST	Sept. 25	H

Letter.	Date.	Discoverer or Observatory.
	1913.	
SU	Sept. 26	H
SV	26	H
SW	29	H
SX	23	M
SY	Oct. 2	S
SZ	4	S
TA	6	S
TB	6	S
TC	24	H
TE	31	H
TF	31	H
TG	28	S
TH	31	H
TJ	June 30	W
TK	30	W
TL	30	W
TM	Oct. 28	S
TN	Nov. 19	R
TO	21	R
TP	1	M
TQ	1	M
TR	Dec. 19	H
TS	19	H
TT	19	H
TU	20	H
TV	20	H
TW	19	LM
I	Feb. 5	C
II	10	C
III	10	C

Abbreviations:—H stands for Heidelberg, the discoveries there being due to Professor Wolf and Herren Kaiser and Massinger; S for Simeis, Crimea, the discoveries there being due to M. and Mme. Beljawsky, and M. Neujmin; M for Dr. Metcalf, Winchester, Mass.; P for Dr. Palisa, Vienna; R for Herr Rheden, Vienna; W for Mr. Wood, Johannesburg; L M for M. le Morvan, Paris.

Planets I, II, III were exceedingly faint objects of about the 18th magnitude, discovered during an unsuccessful search for Albert with the Crossley reflector at the Lick Observatory by Dr. H. D. Curtis. Elements for them are given in *Lick Observatory Bulletin*, 249.

The following planets, that were unnumbered at the date of the last report, have since received permanent numbers: PF 733, PH 734, PY 735, PZ 736, QB 737, (UT) = (GX) = GF 754. Planets QC to QL, of which particulars were lacking in the last report, were discovered by M. Arndt, Neuchatel, 1912 November 4.

The following identities have been established. The second designation by letters is referred to, unless the letters are enclosed in brackets, as (UT). 14 = RA; 94 = PP; 209 = PN; 251 = AN_e; 260 = MF_c; 281 = (TV); 289 = PO; 302 = JF; 492 = SP; 512 = GR; 566 = (JF); 584 = QP; 639 = TD; 701 = KN; 708 = 1892 S; 727 = (FE) = CV; 738 = CF; 741 = GU; 743 = CA; 749 = KO; 753 = AZ = GG. Some other conjectural identifications have been made, but are not given here pending confirmation.

The following have been named:—570 Kythera, 571 Dulcinea, 572 Rebekka, 573 Recha, 574 Reginhild, 575 Renate, 577 Rhea, 579 Sidonia, 580 Selene, 582 Olympia, 584 Semiramis, 585 Bilkis, 586 Thekla, 587 Hypsipyle, 590 Tomyris, 591 Irmgard, 592 Bathseba, 593 Titania, 595 Polyxena, 596 Scheila, 597 Bandusia, 598 Octavia, 599 Luisa, 600 Musa, 601 Nerthus, 603 Timandra, 604 Tekmessa, 606 Brangäne, 607 Jenny, 608 Adolfine, 609 Fulvia, 610 Valeska, 611 Valeria, 612 Veronika, 613 Ginevra, 614 Pia, 615 Roswitha, 616 Elly, 618 Elfriede, 619 Triberga, 621 Werdandi, 622 Esther, 623 Chimæra, 625 Xenia, 626 Notburga, 627 Charis, 628 Christine, 629 Bernardina, 630 Euphemia, 631 Philippina, 632 Pyrrha, 633 Zelima, 634 Ute, 635 Vundtia, 636 Erika, 637 Chrysothemis, 638 Moira, 639 Latona, 640 Brambilla, 641 Agnes, 642 Clara, 643 Scheherazade, 644 Cosima, 645 Agrippina, 646 Kastalia, 647 Adelgunde, 648 Pippa, 649 Josefa, 650 Amalasuntha, 651 Antikleia, 653 Berenike, 655 Briseis, 656 Beagle, 657 Gunlöd, 658 Asteria, 660 Crescentia, 661 Cloëlia, 663 Gerlinde, 664 Judith, 665 Sabine, 666 Desdemona, 667 Denise, 668 Dora, 669 Kypria, 670 Ottegebe, 672 Astarte, 673 Edda, 675 Ludmilla, 676 Melitta, 677 Aaltje, 678 Fredegundis, 680 Genoveva, 681 Gorgo, 682 Hagar, 683 Lanci, 684 Hildburg, 685 Hermia, 686 Gersuind, 692 Hippodamia, 693 Zerbinetta, 695 Bella, 697 Galilea, 698 Ernestina, 699 Hela, 700 Auravictrix, 708 Raphæla, 721 Tabora, 722 Frieda, 723 Hammonia, 724 Hapag, 725 Amanda, 727 Nipponia, 744 Aguntina, 748 Simeisa, 749 Malzovia, 751 Faina.

All the planets up to No. 700 have now received names, and 16 beyond this point.

In addition to the 754 numbered planets, 17 others have had elliptical orbits calculated, and 43 have had circular orbits, making a total of 814 for which orbits of some kind are known.

The Berlin Recheninstitut has made arrangements for the systematic observation of as many planets as possible. The photographic discovery and recovery of planets is carried on at Heidelberg, Simeis, Algiers, Johannesburg, and Winchester, Mass. Dr. Palisa and M. Javelle, among others, take accurate visual observations to supplement the approximate photographic ones. It is considered that for ordinary orbits 3 observations at every third opposition suffice, but more attention is given to planets of special interest.

Dr. Strömgren and M. Hansen have discussed the motion of 624 Hector. The value of μ has steadily increased from 293″·24 in 1907 to 295″·07 in 1913, thus drawing nearer to the value for Jupiter, 299″·13.

433 Eros will be in opposition on September 18 next, and brightest on October 20, when its magnitude will be 10·3. Dr. Witt has given elements for the opposition. The value of μ is 2014″·8293. This has been steadily diminishing for some years, the diminution producing more favourable conditions in 1931 February than those estimated some years ago. The least distance from the earth will be 0·17 or less, little more than half the value at the nearest approach in 1900. A. C. D. C.

Comets in 1913.

A fourth cometary discovery in 1912 was announced (*A.N.*, 4634) too late to be included in the last report of the Council. On the early morning of the last day of the year Mr. B. Lowe of Laura, South Australia, found a faint object with a tail which was invisible with field-glasses, but distinct in a 3-inch telescope. He saw it again on January 3, 5, 6, and 9, moving towards Scorpio, but only approximate places were found and charted, and the announcement of the discovery which had been sent to the Adelaide Observatory was not received till January 7. Unfortunately an error in the announcement and, subsequently, bad seeing conditions prevented accurate places being obtained, but approximate elements and ephemerides were computed by Dr. Crommelin, and by M. Viljev in the hope that images of the comet might be found on photographic plates. No further information concerning it, however, seems to have been published.

Of the other comets of 1912, Gale's Comet (1912 *a*) was followed till May by several observers, and the last observation of it seems to have been made by M. Baldet at Algiers, on May 26 (*A.N.*, 4687, p. 124), when it appeared as a round nebulosity of about 0′·5 in diameter and about 14th magnitude.

Comet 1912 *b* (Tuttle's Comet) was observed at Santiago on 1913 January 3, but was faint and difficult.

No observations of 1912 *c* (Borrelly), which had already passed perihelion before discovery, appear to have been obtained in 1913.

In the year under review (1913) six cometary discoveries were made, five of them in the last four months. The orbits of three were elliptical, but in one case—that of 1913 *c*—the object was previously unknown. Unquestionably the most interesting event of the year was the reappearance of Westphal's Comet (1852 IV.) which has a period of about sixty-one years. On the other hand, there were three members of the Jupiter family—viz., Holmes's Comet (1892 III.), Finlay's Comet (1886 VII.), and Kopff's Comet (1906 IV.), whose returns had been predicted, but of which nothing appears to have been seen. It is likely, however, that the orbit of Finlay's Comet was much perturbed by Jupiter in 1910.

Generally speaking, it may be said that although the comets of 1913 were only telescopic objects, some of them presented points of very considerable interest, either in their physical appearance and behaviour, or in regard to their orbits.

Comet 1913 *a* was discovered by M. Schaumasse at Nice on May 6, as a rather faint object of about $9\frac{1}{2}$ magnitude. The motion was retrograde, and the apparent path lay at first in a north-westerly direction through Delphinus into Lyra. On May 26 it was in the same low-power field with γ Lyræ. It then traversed Hercules, Boötes, and Coma Berenices, and seems to have been last seen at Algiers on August 23 as a very feeble nebulosity. Perihelion was passed in the middle of May at a distance from the Sun of approximately $1\frac{1}{2}$ astronomical units. At the end of May the comet made its closest approach to the earth—viz. about $\frac{2}{3}$ of a unit,—and was in opposition on June 3. The comet was never very bright and varied somewhat in appearance. Sometimes a tail was observed, but more often the comet was merely a round nebulous patch. At first, too, although the coma was more condensed towards the centre, there seems to have been no definite nucleus, and it was never really stellar in character. Herr Silbernagel (*A.N.*, 4705) observed the occultation of a star by the comet on June 7, when the nucleus passed either directly over or very close to the star, which for the time was suspected to be blurred and reddish. On its emergence from the coma it became sharp and bright as before. The orbit did not show any sensible deviation from a parabola.

Comet 1913 *b* was found on September 1 by the Rev. J. H. Metcalf at South Hero, Vermont. It was at first thought it might be Westphal's Comet, for which search ephemerides had been computed on various assumptions as to the date of perihelion. Further observations, however, at once proved it to be a new object. It passed its perihelion about a fortnight after discovery at a distance from the Sun of a little over $1\frac{1}{3}$ units. It was nearest the Earth about October 8, when it was approximately $\frac{2}{3}$ of a unit distant. At discovery the comet was moving N.N.W., and

after passing within 13° of the Pole at the end of September it subsequently travelled through Cepheus, Cygnus, Vulpecula, Delphinus, the western boundary of Equuleus, and crossed the Equator in Aquarius about two months after discovery. The comet, though never a naked-eye object, was fairly bright telescopically at the end of September, but faded gradually in October. It had no definite nucleus.

There was at first some suspicion that the orbit was elliptical, but further observations did not corroborate this.

Comet 1913 *c* was discovered by M. Neujmin at Simeis, Crimea, on September 6. It was quite a small and faint object of about 10th or 11th magnitude, and soon became fainter still. So strange was its appearance that there was at first some uncertainty as to whether it was a comet or a minor planet. Moreover, its aspect showed considerable fluctuations. Some observers described it merely as a stellar point. Professor Barnard (*A.N.*, 4690), using the 40-inch Yerkes refractor, drew it on September 9 with a nebulous appendage in a *s.f.* direction, but found the nucleus indistinguishable in appearance from two neighbouring stars with a power of 460 diameters, though it was less stellar with 700. He adds that in the observations for position one would have readily taken it for an asteroid, as the nebulosity was faint and diffused and was not noticeable in the measures. He further states that he had not before seen such a striking case of a comet being essentially all nucleus. A photograph taken at Heidelberg on September 24 shows a very broad short fan-shaped tail in position angle 170°. On December 31 Professor Schorr photographed it at Bergedorf and found the magnitude 15.

Another point of much interest is that the orbit proved to be unquestionably elliptical. The elements found by Drs. Einarrson and S. B. Nicholson, and by Herr Stracke are very similar, and indicate a period of about eighteen years, so that the comet is a third member of Saturn's family, of which the only two previously known were the comets of Tuttle and Peters. The observed path lay in Cetus, Pisces, and Pegasus. The comet had passed perihelion about three weeks before discovery at a distance of about $1\frac{1}{2}$ units from the Sun.

Comet 1913 *d* was found by M. Delavan at La Plata on September 26, and proved to be Westphal's Comet (1852 IV.). The return was 148 days earlier than that assigned as most probable by M. Viljev. When found the comet was near the north boundary of Aquarius, and it subsequently passed through Equuleus, Delphinus, and Vulpecula into Cygnus. It was about a degree from α Cygni on December 7 and 8. It is rather curious that the paths of three of the comets of 1913—viz., those of Schaumasse, Metcalf, and Westphal—should have been so close together in Delphinus, their tracks at one point approaching one another within 7°. On October 22 Metcalf's and Westphal's Comets were in the same telescopic field. In physical appearance Westphal's Comet underwent a quite remarkable change. It was fairly bright in September

and the early part of October, and on September 28 Dr. Kritzinger at Bothkamp, using a comet sweeper, observed a tail rather more than 1° long, and photographed it at a length of $3\frac{1}{2}°$. At that time the nucleus was well defined and the coma 20′ in diameter. On October 1 the comet was just glimpsed with the naked eye. The conditions of the comet's apparition were not the most favourable, but as perihelion was not till November 26 it was expected to become still brighter. The comet, however, completely failed. The falling-off in light seems to have been first reported by Mr. W. H. Steavenson; and on October 22, when it was in the same field with Metcalf's Comet, Dr. Crommelin found both to be of the 9th magnitude. The comet continued to fade, and by November 22 Professor Schorr found it from photographs to be between the 16th and 17th magnitudes. On November 23 it was practically invisible. This strange behaviour of Westphal's Comet has been compared to that of Holmes's Comet (1892 III.), which also faded rapidly after being brighter at discovery—perhaps in consequence of some explosion which caused rapid expansion and consequent falling-off in light.

Comet 1913 *e* was discovered on October 23 by Herr Zinner at Bamberg near β Scuti Sobieskii. It was only of magnitude 10, but had a short tail. The comet travelled south-eastwards into Capricornus, Piscis Australis, and Sculptor, and at the end of the year was in Fornax Chemica. Early computations of its orbit showed it to be identical with Giacobini's Comet (1900 III.) with a period of about six and a half years. It has been pointed out that at its descending node the comet's orbit is not far inside that of the Earth, and that meteors connected with the comet are possible early in October. The date of perihelion was November 2.

Comet 1913 *f*.—The last discovery of the year was made on December 17 at La Plata by M. Delavan, who had already found Westphal's Comet. The new object was of about the 11th magnitude, and appeared as a small round nebulosity brighter in the centre and approximately 1′ in diameter. It was situated in the north-west part of Eridanus and was travelling towards Cetus, but the motion was so slow that the determination of the orbit was at first difficult. The earlier sets of elements published did not suggest that the comet was likely to become very conspicuous, but from observations in 1914 January both Dr. Crommelin and Herr Biesbroeck found corrections to the orbit which put perihelion as late as near the end of October. It is very remarkable for a comet to be bright enough to be seen ten months before perihelion, and as, owing to the large inclination of the orbit, it will be not unfavourably placed for morning observations in the northern hemisphere about the time of its nearest approach, it seems quite likely that it may become a really brilliant object.

The following are amongst the papers bearing on Cometary Astronomy published in 1913:—

In *A.N.*, 4698, Herr Cuno Hoffmeister discusses still further the relationship between the η Aquarids of May and Halley's

Comet. He points out that the return of the comet was marked by a sudden and decided increase in the activity of the meteoric radiants, and that the maximum coincided with the time of the closest approach of the orbits of the Earth and the comet. From a discussion of the available material he deduces the following elements for the meteoric stream :—

$$\left.\begin{aligned}\Omega &= 45^\circ\ 13'\\ \omega &= 99\ 41\\ i &= 162\ 38\end{aligned}\right\}\ 1900 \qquad \begin{aligned} e &= 0{\cdot}96682\\ q &= 0{\cdot}59480\\ \pi &= 144^\circ\ 54'\end{aligned}$$

The differences (C – M) between the comet's orbit found by Drs. Cowell and Crommelin and the orbit of the meteors are :—

$$\begin{aligned}\Delta\Omega &= +12^\circ\ 3' \qquad & \Delta e &= +0{\cdot}00046\\ \Delta\omega &= +12\ 1 & \Delta q &= -0{\cdot}00765\\ \Delta i &= -\ 0\ 25 & \Delta\pi &= +24^\circ\ 4'\end{aligned}$$

In an article in the *Observatory* (No. 459) Professor Eddington considers the distribution of cometary orbits. He dismisses as untenable the ejection theory of comets and the hypothesis that they come from outer space—in which case there would be a great preponderance of hyperbolic orbits and a clustering of cometary aphelia towards the solar apex.

Assuming the theory now generally accepted of cometary origin in the original nebula of the solar system to be correct, he suggests that the concentration of aphelia, such as those to which Professor W. H. Pickering has drawn attention (*M.N.*, lxxii. p. 741), with centres at long. 97°, lat. – 16°, and long. 270°, lat. – 9°, and a third concentration about long. 270°, lat. – 70°, may indicate knots or extensions of the nebula in those directions. But he adds that perhaps rotation should be taken into account, since only those parts which had no transverse motion could come within our range and be recorded as comets. Professor Eddington endorses Dr. Crommelin's suggestion that the prevalence of comets with very long periods is a case of the "survival of the fittest," since those which approach the Sun frequently would be more quickly dissipated and become effete.

Definitive elements of four comets were published during 1913. In two cases the most probable orbit is hyperbolic, one is elliptical, and one parabolic.

Comet 1880 II. By J. Polak (*A.N.*, 4630).

T = 1880 July 1·73918, Berlin M.T.

$$\left.\begin{aligned}\omega &= 145^\circ\ 11'\ 4''{\cdot}88\\ \Omega &= 257^\circ\ 15'\ 28''{\cdot}94\\ i &= 123^\circ\ 3'\ 30''{\cdot}54\end{aligned}\right\}\ 1880{\cdot}0$$

$\log q = 0{\cdot}2587369$

$e = 1{\cdot}0008409$

Comet 1899 V. (Giacobini). By K. Lous (*A.N.*, 4631).

T = 1899 Sept. 14·93750, Berlin M.T.

$$\left.\begin{aligned}\omega &= 10^\circ\ 47'\ 11''{\cdot}8\\ \Omega &= 272^\circ\ 13'\ 25''{\cdot}5\\ i &= 76^\circ\ 56'\ 32''{\cdot}2\end{aligned}\right\}\ 1900{\cdot}0$$

$\log q = 0{\cdot}251842$

Comet 1906 IV. (Kopff). By G. Zappa (*A.N.*, 4633).

Epoch 1906 Aug. 27·5, Berlin M.T.

$M = 17^\circ\ 29'\ 43''\cdot4$

$\omega = 19^\circ\ 49'\ 42''\cdot2$

$\Omega = 263^\circ\ 39'\ 13''\cdot1$ } 2906·0

$i = 8^\circ\ 42'\ 45''\cdot7$

$\phi = 31^\circ\ 4'\ 38''\cdot0$

$\mu = 539''\cdot150$

$\log a = 0\cdot545531$

$p = 6\cdot581$ years

Comet 1907 I. (Giacobini). By K. Dubrowsky and B. Numerow (*A.N.*, 4671).

$T = 1907$ Mar. 19·14368, Berlin M.T.

$\omega = 317^\circ\ 5'\ 57''\cdot1$

$\Omega = 97^\circ\ 10'\ 13''\cdot7$ } 1907·0

$i = 141^\circ\ 39'\ 45''\cdot4$

$q = 2\cdot051674$

$e = 1\cdot001024$

In the case of Comet 1907 I. the hyperbolic orbit makes the mean error of an observation under 2″, whereas on the assumption of a parabolic orbit it is more than 8″. The hyperbolic orbit seems, therefore, to be well established. T. E. R. P.

Solar Activity in 1913.

Sun-spots.—The year 1913 has been emphatically a year of "minimum activity" so far as sun-spots are concerned; indeed, it is more than a century since any year has shown the Sun in a state of such complete and prolonged quiescence. The last minimum fell early in 1901, and since the average interval of time from one minimum to the next is about eleven years and a quarter, we are already a year and a half behind the date when the revival might be expected to begin, and it is still doubtful whether the bottom of the curve has been reached. In the year 1911 there were 183 days without spots; in 1912 there were 246 such days; but in 1913 the spotless days numbered about 320. So also the mean daily spotted area has diminished from 64-millionths of the Sun's visible hemisphere in 1911 to 37 in 1912, and to about 5 in 1913. The number of separate groups observed has also declined; the 62 of 1911, and 39 of 1912, being represented by 15 in 1913. No year has shown so barren a record since 1810.

The two most prolonged seasons of quiescence occurred in the spring, when, from April 12 to June 25, the Sun was practically free from spots; and in the summer, when a similar condition prevailed from July 31 to September 5; but the few groups observed during the more active months were all small and insignificant; the most considerable group of the year appearing on December 30, and continuing into January 1914.

Of the groups observed, two out of three appear to belong to the cycle that has just opened; the others being near the Equator, would seem to be the last efforts of the expiring cycle.

E. W. M.

Solar Research in 1913.

1. *Periodicities.*—A considerable amount of work on periodic cycles connected with the Sun has been published in the last year. A. Ricco has shown (*Mem. d. Soc. d. Spett. Ital.*, 1913, p. 147) that the frequency curve of prominences closely resembles that of sun-spots, but lags slightly behind. It agrees in the relative slope of the ascending and descending branches, also in the slight decrease of recent magnitudes. This same lag has been pointed out by H. Deslandres and L. d'Azambuja for the dark filaments (*C.R.*, clvii. 413), and by A. L. Cortie for magnetic storms (see 10, below). A rough agreement between sun-spot frequency and cyclonic activity on the Earth has been noted by S. Sarasola (*Ann. Obs. of Montserrat*, No. 2). Evershed (*Kod. Bull.*, 28) finds an annual periodicity in prominence frequency with maxima in January and August and minima in April and November. He also points out an apparent earth-effect in the predominant frequency of prominences on the east limb over the west limb. There are signs of similar action in the case of Venus. Royds (*Kod. Bull.*, 33) has analysed the prominence frequency figures by the method of the periodogram and has found periods of $13\frac{1}{3}$, $7\frac{1}{2}$, and $6\frac{1}{3}$ months.

E. Frenkel has applied the same method to an analysis of Wolf's sun-spot numbers (*Zurich Obs. Publ.*, Bd. v.) for short-period terms. A 200-day period is found, and another one indicated at 68·5 days. It is suggested that these are related to the sidereal periods of Venus and Mercury. H. Kimura has analysed (*M.N.*, *R.A.S.*, lxxiii. p. 543) the same numbers harmonically, and has deduced a number of periods, submultiples for the most part of 162, 78, 60, or 50 years. H. H. Turner (*ibid.*, p. 549) has by a different method deduced 156 years as the main period. In a later paper (*ibid.*, p. 714) Turner suggests the analysis of the sun-spot cycle into a Fourier sequence as a convenient method of shortening the heavy periodogram analysis without loss of accuracy. A. A. Michelson (*Ap. J.*, xxxviii. 268) tests Kimura's sun-spot curve by a mechanical analysis. Treating the intervals 1750–1850 and 1800–1900 separately, he finds that though half the interval is common to both, only one period is common to both: namely, the 11-year period. He suggests that the other periods are illusory. This conclusion agrees with E. W. Maunder's, deduced (*M.N.*, *R.A.S.*, lxxiv. p. 112) from the distribution of sun-spots in latitude. Turner (*ibid.*, pp. 16, 82) points out that there is no evidence for the continued existence of any one period during the whole time covered by the observations. His recent attack on the problem based on the recognition of discontinuities is given elsewhere (see report of Oxford University Observatory).

2. *Sun-spots.*—The relation of individual spots to the spot-cycle enters into W. Brunners' investigation of the divergent motions of spots in a group (*Zurich Obs. Publ.*, Bd. v.) Evidence

is adduced to show that these motions are real and are not due to parallactic drifts arising from the separate elements of a spot-group being at different depths.

A different type of motion is considered by C. E. St. John in a series of important papers in which he develops Evershed's so-called radial motion in sun-spots (*Ap. J.*, xxxvii. p. 322, xxxviii. p. 341; *C.R.*, clvii. p. 428; *Observatory*, xxxvi. p. 395). To an extent which must cause meteorologists to envy him his means of analysis, he has been able to trace the constitution and motions of different layers of the solar atmosphere in the neighbourhood of sun-spots. The horizontal drift of gases in the penumbral region varies for different elements and for different lines of the same element. St. John has made out a strong case for the variations being merely a function of the depth of the layer responsible for each individual line. He supports his view by considerations of intensity of lines of one element, by comparison with the magnetic fields given by the separate spot lines, and by observations of the flash spectrum. Certain discordant observations in connection with a study of the solar rotation are also found to fit in with St. John's scheme. For the highest layers of the atmosphere St. John finds an inflow into the spot region, for the lower layers an outflow.

3. *Solar Atmosphere.*—Further evidence on the motions found in the neighbourhood of spots and prominences is given by M. A. Evershed. She finds evidence (*M.N.*, *R.A.S.*, lxxiii. 422) for an outward motion from the centre of a disturbed prominence region, the outward moving gas showing a tendency to fall back subsequently on to the chromosphere. F. Slocum, whose previous work on prominence matter and sun-spots (*Ap. J.*, xxxvi. 265) is thus supplemented, finds (*Ap. J.*, xxxvii. 354) from the study of a large number of prominences indications of horizontal currents which resemble earth winds; they may be in different directions at different heights over the same spot. There is a general tendency to move towards the poles in middle latitudes and towards the equator in high latitudes: this is the exact reverse of the drifts indicated by sun-spots (Dyson and Maunder, *M.N.*, *R.A.S.*, lxxiii. p. 673). H. Deslandres and L. d'Azambuja (*C.R.*, clvii. 413) show that a further distinction between the strong dark filaments and the weaker alignments found in the upper layers of the Sun's atmosphere lies in the fact that the latter do not appear to share in the solar periodicity. Deslandres' work and views on these features are reviewed by A. A. Buss (*Observatory*, p. 225), and with reference to Hale's and Evershed's researches by Ricco (*Mem. d. Soc. d. Spett. Ital.*, 1913, p. 211).

4. *Solar Rotation.*—F. W. Dyson and E. W. Maunder have deduced from the Greenwich photoheliograms of 1874–1912 a small correction to Carrington's elements for the position of the Sun's axis. For the epoch 1850·0 they get $I = 7^\circ\ 10{\cdot}5'$, $N = 73^\circ\ 46{\cdot}8'$. There have been two more spectroscopic investigations published of the solar rotation. J. S. Plaskett and R. E. De Lury have obtained (*Ap. J.*, xxxvii. 73) a value for 1911 agreeing very

closely with Adam's value for 1908. No systematic difference for different elements is found. The curious personal errors of measurement appear to have been reduced, but there are still some puzzling sources of error outstanding. Evershed and Royds (*M.N., R.A.S.*, lxxiii. 554) have obtained a low value for the rate of rotation. They also indicate a range of variation of 2 to 3 per cent. in their results, a variation which may be connected with sun-spots. Between January and April 1913 the equatorial value fell from 1·990 km./sec. to 1·900 km./sec. The April values were obtained in the green and the January ones in the violet—a fact which may point to one source of the discrepancies. The general question of variation cannot be settled until more of the systematic errors have been traced to their source and allowed for or removed.

An attempt has been made by M. Fessenkoff (*C.R.*, clvii. 834) to account for the equatorial acceleration of the Sun in terms of a body of varying density cooling at the surface and becoming less oblate. The deduced acceleration is higher than that observed, but it is possible that a friction term might make his theory accord more closely with the observed values.

5. *Solar Radiation.*—The most important publication in the past year has been vol. iii. of the Annals of the Smithsonian Astrophysical Observatory (see separate note, p. 337). Abbot recognises that the loss through absorption in the upper atmosphere of any considerable amount of radiation below the wave-length 290 $\mu\mu$ would seriously affect the value of the solar constant, which he gives as 1·932 cal. per sq. cm. per min. In this connection a paper by Fabry and Buisson (*Journ. de Phys.*, 1913, p. 196) is of importance. They adduce striking evidence to show that the ultra-violet limit of the solar spectrum is set by an ozone absorption band near 300 $\mu\mu$. If the ozone, created possibly by the ionisation of the upper atmosphere through ultra-violet rays from the Sun, exists in a thin layer at a high altitude, then Bouguer's formula will not apply. An isolated balloon experiment at a height of 14 km. which is quoted by Very as indicating a value of the solar constant as high as 3, points in this direction. The controversy between Very and Abbot is continued in the *Astrophysical Journal* (vol. xxxvii. 25, 130). Some more direct evidence for the high-level ozone layer must be adduced, however, and also for greatly increased solar radiation at great heights, before the Smithsonian value can be seriously shaken.

A point upon which Abbot and many others have insisted has been a marked falling off of the intensity of the solar radiation in the last few months of 1912. This has been generally traced to an eruption of Mount Katmai in June to October 1912. In addition to some very valuable work on improvements and tests of standard apparatus, Abbot has also carried through a study of the distribution of energy in the solar spectrum and of the solar temperature. J. Wilsing (*Pub. d. Astrophys. Obs. zu Potsdam*, No. 96) has carried through a similar comparison of the intensity of light in the Sun's spectrum with black-body radiation. The

respective black-body temperatures obtained for the Sun are 6000° and 6064° on the absolute centigrade scale, and the maximum intensities are at 470 $\mu\mu$ and 482 $\mu\mu$ respectively.

Abbot has further studied the variations of solar intensity over the whole disk. He finds that the contrast between the centre and the limbs increases with the amount of the radiation. He uses this as one argument for looking to the Sun itself for a source of its variation. Belot (*C.R.*, clvii. 757) suggests that the source lies in the passage of belts of zodiacal matter across the Sun's face.

6. *Photosphere.*—In the volume discussed in the last section Abbot gives reasons for the acceptance of his theory of a gaseous Sun. A series of papers have been published on the nature of the photosphere. A. Fowler (*Observatory*, xxxvi. 182) offers physical reasons against the classical view of the cloud-like photosphere: he looks to the pressure and electrical conditions as the origin of the continuous spectrum from a gaseous photosphere. J. F. H. Schulz (*ibid.*, p. 428) argues again for a liquid Sun. J. B. Hubrecht, discussing the darkening of the Sun's limb (*ibid.*, p. 398), gives an account of the views of Abbot, Arrhenius, Julius, and Schwarzschild—and inclines to an explanation in terms of molecular scattering. W. H. Julius (*Ap. J.*, xxxvii. 225, xxxviii. 129) discusses his observations of the solar radiation made at Maastricht during the annular eclipse of the Sun, 1912 April 17. The ratio of the minimum radiation to the maximum was far too small to be consistent with the usual explanation of the darkening of the Sun's limb. The cloud-theory of the photosphere must be abandoned; and in considering radiation from the Sun's surface the layers below the photosphere must also be taken into account. Julius discusses an "irradiation surface" whose form depends on the steepness of the optical gradient.

D. Brunt (*M.N.*, *R.A.S.*, lxxiii. 568) has made a detailed examination of the applications which Julius has made of anomalous dispersion to explain a wide range of solar phenomena. He shows that this theory fails to account for the observed phenomena of the Sun's upper atmosphere, also for the differences between the Fraunhofer lines at the centre and limb of the Sun. The bright details in spectroheliograms also are not explained on Julius's hypothesis. For the chromosphere and prominences the evidence is neutral for the view that anomalous dispersion is a principal factor in causing solar phenomena.

Julius's views on anomalous dispersion as a *vera causa* of solar phenomena have also been criticised by C. Gouy (*C.R.*, clvii. 1105). In general doubtful as to the applicability of laboratory experiments to the Sun, he gives reasons to mistrust the views of Julius from a consideration of the quantity of vapour involved. From quite another point of view S. Chevalier throws doubt in the *Annals of the Zô-Sè Observatory* on our knowledge of fine detail in the photosphere. He points out abnormal refraction of rays in the telescope near the secondary magnifier as a likely source of error.

7. *Eclipses.*—There was no total eclipse of the Sun in 1913,

but results obtained at previous eclipses have been published. In addition to Julius's papers, previously mentioned, and Mitchell's work on the chromosphere (see 8, below), there have appeared a set of beautiful reproductions of corona photographs secured at Soukahras in Algeria in 1905. These have been published by R. Schorr (*Hamburgische Sonnenfinsternisse Expedition*, 1905). They are copies of photographs taken to secure details of the inner corona; the solar image is 19 cm. in diameter. The late F. W. Ristenpart made eclipse observations with a selenium cell during the total eclipse of 1912 October 9 (*Ast. Nach.*, cxciv. 417). The sky was completely cloudy, and observations could only be made on the clouds. Several papers on the shadow-bands have appeared. F. Biske (*Ap. J.*, xxxviii. 192) proves that they cannot be regarded as diffraction phenomena, while K. Groes-Petersen and H. v. Seeliger (*Ast. Nach.*, cxcvi. 293 and 419) discuss them from the point of view of contrast effects. The latter points out that the eye measures second-order changes in brightness rather than first order. E. Freundlich points out (*Ast. Nach.*, cxciii. 369) that no plates are as yet available well suited to test Einstein's deduction from the principle of relativity, according to which light passing near the Sun from a star should be deflected. G. A. Tikhoff obtained photographs of the chromosphere and prominences, also an objective prism spectrum of the chromosphere at the partial eclipse on 1912 April 17 (*Mitt. d. Nikolai-Hauptsternwarte zu Pulkowo*, v. 6). This confirms the work done elsewhere as to the value of observations made off the line of totality.

8. *Spectrum of the Chromosphere.*—S. A. Mitchell has published his measures of the chromospheric spectrum obtained at Daroca in 1905 with the United States Naval expedition (*Ap. J.*, xxxviii. 407). This is a piece of work of first-rate importance, and is likely to hold its place for some time as the standard authority on the subject. 2841 lines between λ 3300 and λ 6200 have been measured, and the hydrogen series has been followed and separated down to H35. Mitchell confirms previous observations, which indicated that the enhanced spark lines rise above the ordinary reversing layer, a conclusion also reached by St. John (see 2, above). Mitchell is inclined to explain their added brightness in part by the fact that at the higher levels they are mixed with hydrogen at reduced pressure. Another piece of research which promises to throw more light on this matter is A. S. King's work on the behaviour of enhanced lines in the tube-arc (*Ap. J.*, xxxviii. 315). Mitchell finds for the reversing layer, which contains most of the low-level lines, a height of about 600 km. He claims that, save for variations of intensity, which exist in other lines beside the special class of enhanced lines, the spectrum is practically identical with the Fraunhofer spectrum. It will require detailed study to confirm or disprove this; it may be said, however, that the identification of the lines is perhaps the most difficult portion of the work, and that Mitchell's identifications will not all hold. It is unlikely that all the coincidences with rare earth spectral lines

will justify the identifications made by Mitchell. Mitchell declares against the presence of radium in the chromosphere, as also does J. Evershed (*Kodaikánal Bull.*, No. 27). The latter worked on his 1900 eclipse chromospheric spectrum and also on a reproduction of Mitchell's spectrum. The two investigators agree as to the absence of evidence for radium and its emanation, neon, argon, krypton, and xenon.

9. *Sun's Magnetic Field.*—G. E. Hale has now published (*Ap. J.*, xxxviii. 27) a full account of the Mount Wilson observations on the Sun's general magnetic field. A discussion of his preliminary account appeared in last year's report. It will suffice now to state that the spectral lines were photographed through a quarter-wave plate built up of mica strips, successive strips having their principal sections at right angles. The phenomenon is entirely a low-level one, falling away rapidly with increasing height. The Sun may be regarded as a spherical magnet having a polar field of 50 gauss with the same polarity as the Earth. There is very fair agreement between the observed field and the theoretical field worked out by F. H. Seares (*Ap. J.*, xxxviii. 99). Hale discusses various possible explanations of the observed field, and seems inclined to favour one in terms of the rotation of an ionised atmosphere. D. Brunt (*Ast. Nach.*, cxcvi. 169) applies Hale's observed value for the Sun's field to test various theories that have been advanced. He finds that the charges required by the explanation in terms of the rotation of electrical charges are too great for the Sun to hold, and that other rotational explanations also fail. More hopeful results are found from the theory of local whirls, though some explanation is still required for a preponderance of whirls of one polarity in the same hemisphere. K. Birkeland (*C.R.*, clvii. 394) also looks upon Hale's results as due to local whirls or concealed spot-fields. His own value for the Sun's field was very different. The same may be said of H. Deslandres' value of the general field (*C.R.*, clvii. 517). He obtains an equatorial field of 10^{-7} gauss in the opposite direction to Hale's field, from a study of the motions at the bases of prominences observed at the limb. His result is a high-level result, and he suggests a reconciliation with Hale's 50 gauss in terms of a series of layers charged successively in opposite senses. H. Chrétien suggests (*C.R.*, clvi. 192) that the equatorial acceleration may, when more observations are available, serve as a criterion between different rotational explanations; and K. Birkeland (*C.R.*, clvii. 104) shows that whichever sign the Sun's magnetic field has, the magnitude of the field will be increased by the emission of ions and electrons. He quotes laboratory experiments in support of his views.

J. A. Harker has given an account (*M.N.*, *R.A.S.*, lxxiii. 562) of some experiments made at the National Physical Laboratory, by G. W. C. Kaye and himself. These experiments show that most substances which can withstand high temperatures emit electricity when heated. He concludes that the solar atmosphere is a highly conducting medium and suggests that these results must

have some application to solar physics, in explaining the enormous local currents found by Hale in sun-spot vortices.

10. *Miscellaneous.*—J. W. Nicholson (*Observatory*, xxxvi. 103), gives an account of his physical interpretation of the coronal spectrum. All but a few of the unknown lines—and these exceptions include the green line at λ5303—may be derived from a system with a positive nucleus (bearing a charge of five times the charge of an electron) surrounded by a ring of electrons. He finds that most of the lines come from negatively charged systems, *i.e.* systems with a ring of more than 5 electrons. This suggests that there are many free electrons in the corona.

A. L. Cortie (*M.N.*, *R.A.S.*, lxxiii. 148, 432, 539) has further developed his views on the connections between sun-spots and magnetic storms on the Earth. The association depends on the nature of the spot, its irregular structure. It is independent of the position of the spot on the disc. Rays carrying negatively charged electrons diverge from the disturbed area, and a storm arises when the Earth dashes into a cloud of these. Eclipse results show sets of coronal streamers connected with recurrent magnetic storms.

S. Chevalier (*Annals of Zô-Sè Observatory*, vi.) has studied photographically the Sun's polar and equatorial diameters. He concludes that the polar diameter is slightly larger by an irregular amount. He obtains a mean diameter of 31′ 59″·93 as against Auwers' value of 31′ 59″·26. It is not clear that the results are free from systematic error.

R. S. Capon (*M.N.*, *R.A.S.*, lxxiii. 361, 732) explains some of the anomalous motions of sun-spots in terms of refraction in the Sun's atmosphere and urges the need to apply a refraction correction in determining the positions of spots.

The Triennial conference of the International Union for Solar Research took place at Bonn, July 30–August 5. Full accounts of the meeting are given in the following periodicals: *Ap. J.*, xxxviii. 301; *Ast. Nach.*, cxcv. 411; *Mem. d. Soc. d. Spett. Ital.*, 1913, 165; *Observatory*, xxxvi. 356. F. J. M. S.

Solar Radiation.

In the last report of the Council the establishment of the short-period variability of the Sun was foreshadowed, though the observations had not been fully discussed. Mr. Abbot gave an account of the completed researches to the International Union at its Bonn meeting. The main feature is the agreement between the independent observations at Mount Wilson in California and Bassour in Algeria, which Mr. Abbot has represented by a diagram showing the grouping of pairs of observations about a diagonal line at 45° inclination.

The coefficient of correlation between the two stations comes

out $r = 0{\cdot}52 \pm 0{\cdot}07$; or, omitting three observations marked with a double query, the value of r rises to 0·60.

Mr. Abbot gives the following interpretation :—

"The results given in the diagram show conclusively that if high values of the solar radiation (outside the atmosphere) are found from Californian observations, the values found from Algerian observations will be high also, and *vice versa*. In other words, the fluctuation of the 'solar constant' values which had been found in California in former years is now shown to be no local phenomenon due, perhaps, to atmospheric disturbances, but rather a phenomenon which is general over the Earth's surface and which must be attributed to causes outside the Earth altogether. It would be conceivable that such a cause might be the interposition of meteoric dust or other matter between the Earth and the Sun : but other evidence, which is more fully explained in vol. iii. of the *Annals of the Astrophysical Observatory*, shows that we must attribute the changes to the Sun itself, and not to the interposition of matter between the Earth and the Sun. Thus we may conclude that the Sun is variable, having not only a periodicity connected with the periodicity of sun-spots, but also an irregular, non-periodic variation, sometimes running its course in a week or 10 days, at other times in longer periods, and ranging over irregular fluctuations of from 2 to 10 per cent. of the total radiation in magnitude." (*Report of Smithsonian Astrophysical Observatory* for 1913, p. 5.)

The variations sympathetic with sun-spots are shown in another diagram of 40 observations ; and Mr. Abbot gives as the numerical result : "An increase of radiation at the Earth's mean distance from the Sun of 0·07 calorie per square centimetre per minute appears to attend an increased spottedness of the Sun represented by 100 Wolf sun-spot numbers." If we use the correlation method we find

$$r = 0{\cdot}53 \pm 0{\cdot}07,$$

and the linear relation found is

$$\text{solar constant} = 1{\cdot}921 + {\cdot}00035 \times \text{Wolf's number}.$$

The coefficient ·00035 is smaller than the ·0007 estimated by Mr. Abbot from the diagram, but this is intelligible to those familiar with the correlation method. The constant 1·921 corresponds to zero spottedness, and thus differs from the 1·932 given by Mr. Abbot, which corresponds closely to the mean spottedness for the observations tabulated (Wolf's number = 36·6).

It is interesting to note that the radiation *increases* with the spottedness. In 1910 Mr. Abbot suspected a *decrease*, chiefly because (as he states in the report to International Union for Solar Research) "the results of numerous investigators have shown that the temperature of the Earth is lower when the sun-spots are at the maximum." To explain the difference he calls attention to an investigation by Dr. Magelssen of Christiania, who finds that the decrease of temperature with sun-spots is more strongly marked in

the winter months (at Christiania and Berlin) than in the summer. He infers that there is "a tendency to decrease temperature which is operative *independently of the altitude of the Sun*, and which overpowers the direct influence of increased solar activity."

A discovery of great importance for future work in this field is that when the solar radiation is high, the contrast between the centre and edge of the disk is high also, *in all wave-lengths*. This puts a new method at the disposal of astronomers, and one which on the face of it does not demand very costly apparatus.

H. H. T.

Double Stars.

The abbreviations used are—

M.N. : *Monthly Notices, Royal Astronomical Society.*
A.J. : *Astronomical Journal.*
A.N. : *Astronomische Nachrichten.*
L.O.B. : *Lick Observatory Bulletin.*

New Doubles and Measures of known Pairs.—Nos. 27 and 28 of the *Journal Astronomique*, issued from the Observatory of the University of Lille, contain 112 new doubles discovered by M. Robert Jonckheere with the 13¾-inch refractor. These bring up M. Jonckheere's discoveries to 1033, of which 614 pairs are under 3″ separation.

An analysis of M. Jonckheere's new doubles found since 1906 will be found in the *Comptes Rendus*, 1913 March 25.

The *Transvaal Circular*, No. 13, contains the first series of measures of Southern doubles made with the 9-inch Grubb refractor. There are in all 396 pairs representing the work up to the end of 1911. Of these 220 pairs are under 2″ separation.

A second series of measures up to the end of 1912 is in the circular No. 4 of the Union Observatory. In this case there are 200 pairs, of which 126 are under 2″ separation. In both sets Mr. Innes has made estimates of colour which should prove useful in future investigations. Mr. Innes has already established fairly rapid motion in a good percentage of the stars, and these circulars as issued from time to time will form valuable supplements to the "Reference Catalogue."

The Rev. T. E. R. Phillips contributes to the *M.N.*, 1913 January, some measures made with the 8-inch refractor belonging to the Society. There are 54 Struve pairs under 5″ separation. There are also 11 Herschel pairs measured with a 12¼-inch reflector.

In the same number the Rev. T. Espin contributes 80 new pairs, bringing his total discoveries to 1191. Of these 47 are under 5″ separation.

The results of measures of double stars made with the 28-inch Greenwich refractor during the year 1912 are in *M.N.*, 1913 December. Of the 515 pairs measured 234 are under 1″ separation.

A very useful set of measures, by K. Schiller, with the 29-cm.

refractor of Bothkamp Observatory, is in *A.N.*, 4680. The stars are between 70° and 90° N. Dec., and were measured in the years 1908–11. There are 59 pairs under 5″ separation and 106 over 5″.

Dr. Doberck still devotes much time to the measurement of stars from a well-chosen observing list. In *A.N.*, Nos. 4664 and 4695, will be found measures of 61 pairs under 2″ and 165 pairs over 2″. Many of the latter are for proper motion.

In *A.N.*, Nos. 4659 and 4693, Dr. Abetti gives measures of 200 pairs made with the 38-cm. refractor of the Observatory of the Collegio Romano. These also are mostly for proper motion.

B. Fessenkoff, with the Sorbonne photographic refractor of the Paris Observatory, measured 130 Σ and OΣ pairs, of which 51 are under 5″ separation. The results are in the *Bulletin Astronomique*, 1913 March.

In *A.J.*, 633, Professor Leavenworth publishes his measures made in the years 1906–11 with the 10½-inch refractor of the University of Minnesota Observatory. There are 113 pairs, of which 92 are under 3″ separation.

In *A.J.*, 644, there are measures, made in the years 1910–11–12, of 140 pairs by H. J. Woods with the 11½-inch Washburn refractor. Of these 130 are Herschel pairs.

In *A.J.*, 638 and 644, Professor Barnard gives his measures of Sirius and Procyon made with the 40-inch Yerkes telescope. These and some by other observers are—

		°	″	
Sirius	1910·83	86·9	9·00	Barnard
	11·21	87·3	9·62	Barnard
	12·08	84·7	9·91	Barnard
	12·15	84·7	9·82	Innes
	13·05	82·3	9·96	Barnard
	13·14	82·6	10·03	Bowyer
	13·25	81·6	9·23	Jonckheere
Procyon	1910·03	26·3	5·21	Barnard
	13·14	34·3	...	Bowyer
	13·16	42·6	5·09	Barnard

"*Measures of Proper Motion Stars made with the 40-inch Refractor of the Yerkes Observatory, in the Years 1907 to 1912,*" *by S. W. Burnham.*—This volume is published by the Carnegie Institute, and contains over 9500 measures which have been made to determine the proper motions of the brighter stars with reference to the faint stars near them. If these faint stars are fixed, then the absolute proper motions of the large stars are known. These measures have been mentioned in the annual reports, but all are now in one volume. A valuable article pointing out the most interesting features of this volume will be found in *Popular Astronomy*, No. 208.

In *L.O.B.*, Nos. 223 and 240, Professor Aitken publishes 200

new double stars, which bring his discoveries up to 2600. As will be seen, a large number of these are quite beyond the reach of ordinary observers. There are—

242 pairs	under	0″·25 separation	
562 ,,	between	0·25 and 0″·50	separation
535 ,,	,,	0·50 and 1·0	,,
585 ,,	,,	1·0 and 2·0	,,
659 ,	,,	2·0 and 5·0	,,
17 ,,	over	5·0	,,

In *A.J.*, No. 229, among a list of radial velocities of 915 stars will be found many double stars, such as η Cassiopeiæ, ζ Cancri, ϵ Hydræ, Procyon, δ Equulei, etc.

Computational and Theoretical Papers.—S. G. Cederstrand, in *Arkiv för Matematik, Astronomi och Fysik*, Band 8, No. 34, obtains for OΣ 4 a parallax of 0″·115; but finds a parallax for Σ 19 indeterminate. The material for discussion was derived from 18 plates obtained with the 162-mm. refractor of the Stockholm Observatory in 1907–8. Both stars, together with four comparison stars used for each, are on the same plates. His deduced proper motions seem to rest on rather poor material.

Professor Aitken, in *A.S.P.*, No. 146, finds Aitken 88 a binary of 12·12 years' period. The maximum separation does not exceed 0″·2.

Mr. Innes, in No. 6 circular of the Union Observatory, finds a period of about 175 years for the binary "Brisbane 3574."

Dr. Doberck, in *A.N.*, 4649, finds a period of 25·6 years for β 101 (9 Argus).

Mr. Robert Jonckheere, in No. 28 of the *Journal Astronomique*, gives ephemerides for Σ 60, OΣ 38, Σ 3121, OΣ 208, and Σ 1523. These are based on the orbits in Dr. See's *Stellar Systems*.

In *Knowledge*, 1913 April and August, are some notes on double star work by Mr. Bellamy and the late Mr. Henkel.

In *The Observatory*, No. 467, there is an article by Mr. Lewis, "On the Magnifying Powers used by Double Star Observers." From a discussion of some thousands of observations he concludes that the favourite power is well represented by $140\sqrt{\text{aperture}}$ in inches. T. L.

Variable Stars.

The number of new variables recorded in a single year has of late considerably declined. Whereas in 1910 the A.G. Committee assigned provisional numbers to over a hundred stars, the number of discoveries has steadily fallen, and during the past year scarcely thirty new objects have received this form of official recognition. The year has been unmarked by the outburst of any conspicuous nova.

Observational work on variable stars has, however, been steadily pursued with increasing energy. More detailed attention is given to particular objects, the work grows steadily more systematic, old methods are followed with greater care, new methods of brilliant promise are being developed, and observations are receiving something of that measure of refined discussion which is necessary to bring out their full value. There is much to suggest that this branch of astronomy is emerging from its first youth.

Of the work which has been accomplished little can be said here, because it is too extensive to notice in detail. And this is the less necessary since the excellent *Jahresbericht*, which we owe to the late Dr. Wislicenus, will shortly put us in possession of a complete abstract of what has been done in this, as in other fields of astronomy. But the shortest notice cannot overlook the admirable memoir by Professor S. I. Bailey on the variable stars in the cluster Messier 3 (*Annals of H.C.O.*, vol. lxxviii. part 1), which recalls the similar work by the same author on the ω Centauri cluster. In Messier 3 he has found 137 variables, all of which approximate closely to a single type. In no case does the period, when ascertained, differ much from half a day, and the range is generally about two magnitudes. Such results offer a problem of very great interest.

As the study of variable stars becomes more thorough and systematic, the question of classification must become more important. Hitherto none of the several systems proposed has gained any general acceptance, and, on the whole, increase of knowledge in this case makes it easier to criticise any particular scheme than to lay down definite principles. Thus the most elementary distinction which suggests itself is the broad difference between periodic and irregular variation. Yet in practice such a line of division can scarcely be drawn with the necessary definiteness. On the one hand, it is impossible to assure ourselves that a quite simple period is really constant and absolutely free from periodic or secular changes, or that the variation is repeated in successive periods with absolute fidelity. On the other hand, it is difficult to assert that in the case of irregular stars the variation cannot be represented by a finite number of periodic functions. A rather elaborate scheme of classification has been formulated by Mr. Stanley Williams (*Journal B.A.A.*, xxiii. p. 133). This has been discussed by Dr. S. D. Townley (*Publ. Astr. Soc. Pac.*, xxv. p. 239). A particular question which has received some consideration concerns the relationship of the so-called cluster type to the δ Cephei type. The most definite contribution to the problem is due to Dr. Kiess (*L.O.B.*, 232), who has studied the star RR Lyræ both as a cluster variable and as a spectroscopic binary. The result, so far as it goes, tends to abolish the distinction between the two types, which had rested chiefly on the statistical interpretation of the combined frequency curve of the periods in the two classes of stars. A question of nomenclature is also involved. The name "Cepheid" is a singularly unhappy one, but it has unfortunately gained some

currency. Dr. Hartwig, in his introduction to the latest A.G. Catalogue of variables (*V.J.S. der A.G.*, xlviii. p. 287), suggests the name "Blinkstern." To its general adoption the difficulty of finding appropriate equivalents in other languages would seem to be an obstacle.

The outstanding event of the past year has been the application of the photo-electric cell to stellar photometry. It has been known for some years that the alkali metals when exposed to light give out negative corpuscles, even when the light is of weak intensity. This principle has been applied by Elster and Geitel in the construction of photo-electric cells. Such a cell consists of a glass bulb on a part of the interior of which a film of potassium, for example, has been deposited, and which is filled with an inert gas at very low pressure. When the film is maintained at a certain electric potential and light is allowed to fall upon it, the liberated corpuscles carry a current depending upon the intensity of the incident light to a terminal which is connected to a sensitive electrometer. The effect can thus be determined and a measure of the intensity of the light is obtained. Potassium and rubidium, being radio-active, emit corpuscles even in the dark—a fact discovered by Sir J. J. Thomson (*Phil. Mag.*, x. (1905) p. 584). This causes a disturbing effect, which may be practically avoided by the use of sodium or cæsium. Cells containing the latter metal have not hitherto been available in astronomical work.

Attention may be directed to two papers of great interest: one by Professor E. Meyer and Dr. H. Rosenberg (*V.J.S. der A.G.*, xlviii. p. 210), which was read by the latter at the August meeting of the A.G. in Hamburg; the other, by Dr. P. Guthnick, on the variation of the spectroscopic binary β Cephei (*A.N.*, 4701). The two pieces of work are in a sense complementary. Guthnick used a sodium cell placed at his disposal by Elster and Geitel, and adopted the simplest and most direct method of measuring the current excited by the incident light. This consists in measuring with a chronograph the time required for a definite displacement of the electrometer thread, the electrometer being of a pattern designed by Elster and Geitel. For the purpose in view this proved entirely satisfactory. As a comparison star α Cephei was used, and the result is to assign to β Cephei a light curve showing all the characteristics of a cluster variable with a range of about $^{m}\cdot08$ and a period of about $4\frac{1}{2}$ hours. The mean error appears to be about $^{m}\cdot008$, and it is interesting to notice that the most serious limitation on accuracy is set by the differential effect of cloud absorption on stars of different spectral type. Evidently the full possibilities of the method will only be realised when it is applied at the most favourably placed observatories. It is also of interest, in view of the small range of variation, to notice that anterior observations by purely photometric means had enabled Herr Guthnick to determine a satisfactory epoch of maximum.

The other paper covers different ground. It contains no particular application to any astronomical problem, but is concerned

with a thorough examination of the conditions on which an accurate photometric method depends, and of the practical arrangements which are suitable when the apparatus is used in conjunction with a moving telescope. It was found that under the conditions of greatest sensitiveness the method of measuring the time of a definite swing in the electrometer became unreliable. Accordingly the method adopted by Dr. Bronson on the suggestion of Sir E. Rutherford (*Phil. Mag.*, xi. (1906) p. 143) was followed. This consists in connecting the electrometer not only to the electrode in the cell, but also to earth through a high resistance (of the order of 10^{11} ohms). Under these circumstances the deflexion of the electrometer reaches a limit when the leak through the resistance equals the current in the cell. Further than this, a compensating current was sent through the resistance by applying a potential difference which was measured by a bridge method. Even with these modifications and the advantages of a null method thus obtained, the investigators were not satisfied; for they found that the cells do not give an effect proportional to the exciting cause. If

$$J_1/J_2 = c \,.\, E_1/E_2,$$

where J_1, J_2 are the light intensities and E_1, E_2 the corresponding currents, they found that $c = 0{\cdot}72$ for the Elster and Geitel cell, and though they succeeded in constructing cells of a new pattern for which c was as large as 0·94, they could not obtain perfect proportionality ($c = 1$), nor were they satisfied that c was even constant. Hence, finally, they decided to reduce the incident light by interposing a pair of Nicols and to measure the intensity by rotating one of them, until the photo-current reached a definite amount. Using a 5-inch refractor on a star of type A and magnitude 6, they assess the accuracy of a single setting at $^{m}{\cdot}003$ or $^{m}{\cdot}004$. Besides this extraordinary precision, the method possesses two striking merits: the operation of the cells is independent of temperature, and they are practically free from fatigue effects.

It is interesting to compare these results with those obtained by Dr. Guthnick's simpler method of measurement. Such discrepancy as there may be between them may be accounted for by supposing that he was content with a sufficient but not extreme sensitiveness, and by the fact that he was concerned with a comparatively small range of magnitude. The effect of a want of proportionality in the cell would be an error in the magnitude-scale of his light-curve. This is possible, but in the particular problem it would not affect materially the value of his results. It could be avoided by a preliminary calibration of the cell.

A suggestion may perhaps be made relative to the extension of the method to fainter objects. A well-known method is to use extra-focal photographic images or, better, the images produced by Schwarzschild's Schraffierkassette, and to measure the density of the film. It seems quite possible that this could be done with greater accuracy by means of the photo-electric method than by any photometric process. The feasibility of this combination of

photo-electric and photographic methods is strongly suggested by the success of Koch of Munich, in the apparently analogous problem of determining the intensity curves of photographic spectra. H. C. P.

Stellar Distribution and Drift.

Stellar Parallaxes.—A new series of parallaxes determined with the Yerkes 40-inch refractor has been published by F. Slocum and S. A. Mitchell (*Astrophysical Journal*, **38**, p. 1). Fourteen stars have been measured, mostly stars of insignificant proper motion; and, as might be expected, the parallaxes of the majority are inappreciable. There are, however, three faint stars with annual motions exceeding 1″, and these give parallaxes of ·″125, ·″124, and ·″108 respectively. The parallax of Nova Geminorum was investigated and found to be inappreciable.

Radial Velocities.—By the publication of the radial velocities of stars of later type in *Lick Bulletin*, No. 229, the greater part of the material accumulated up to the present has become available for investigation. Bulletins 195, 211, and 229 form together a nearly complete catalogue of radial velocities containing about 1350 stars. Mention must also be made of the publication in book form of W. W. Campbell's Silliman Lectures of 1910, which give a comprehensive account of recent developments in our knowledge of stellar motions.

The Two Star-Streams.—G. C. Comstock (*Astron. Journ.*, No. 655) has made an investigation of the proper motions of 479 faint stars based on micrometric measures, using Schwarzschild's abbreviated method of determining the apex and vertex. The following are his results:—

Magnitude.	Apex.		Magnitude.	Vertex.	
	R.A.	Dec.		R.A.	Dec.
7·0–10·0	280°	+58°	7·0–13	277°	−28°
10·0–13	288°	+71°			

Additional evidence is thus afforded that the declination of the solar apex increases rather rapidly with the faintness of the stars—a fact which is usually held to imply that the proportion of stars of the second drift increases with diminishing magnitude. The vertex for these stars lies not far from Dyson's and Beljawski's positions: that is to say, some 15° from the majority of the older determinations. The ratio of the minor to the major axes of the velocity-ellipsoid for these faint stars proves to be 0·62, in good agreement with determinations from other data.

Comstock also concludes from this discussion that the average stellar distance is nearly inversely proportional to the magnitude, and that the product, mean centennial motion × magnitude, is approximately 35″. This would make the motions of the faint stars considerably greater than is generally supposed. The tendency

of the paper is to show that the faint stars are closely bound up with and exhibit the same phenomena of motion as the bright stars.

An important memoir by C. V. L. Charlier (*Lund Meddelanden*, series ii., no. 9) discusses the motions of the stars of Boss's Preliminary General Catalogue by correlation methods. His investigation leads to a position of the vertex

R.A. 283° Dec. −19°

with a ratio of the axes of the ellipsoid 1 : 0·50.

His analysis corresponds to a generalised ellipsoidal hypothesis, and his conclusions are opposed to the representation of the motions as due to two intermingled drifts. Probably his objection is connected with a difficulty found by F. W. Dyson (*Monthly Notices*, lxxiii. p. 420) that the two-drift theory does not give a sufficient spread of the motions in the directions of the vertices.

The main points of discrimination between the two-drift and ellipsoidal hypotheses appear to be :—

(1) The skewness of the velocity-distribution,
(2) The spread of the distribution,
(3) The existence (or non-existence) of two maxima.

As regards (1), the advantage is admittedly with the two-drift hypothesis. The second point is now shown to be better fitted by the ellipsoidal hypothesis. With regard to (3) the evidence seems slightly in favour of the two-drifts. According to the relative importance attached to these three criteria, different views will be held as to the merits of the two methods of approximation.

Spectral Type.—The properties of the different spectral classes of stars present many puzzling features. Perhaps the most striking difficulty is that the type M stars, generally regarded as the latest of the types, appear in parallax discussions (limited to the nearest stars) to be the faintest of the stars, whereas in the more general statistical discussions they appear to be nearly the brightest type. H. N. Russell (*The Observatory*, xxxvi. p. 324) has put forward the view that there are two distinct classes—Giant and Dwarf stars—in each type; the Giants being in a diffused state and in an early stage of evolution, and the Dwarfs in a concentrated and later stage. The order of evolution would thus be from M (Giants) to B and back again to M (Dwarfs). Some objections to this view are noted by A. S. Eddington (*The Observatory*, xxxvi. p. 467).

The peculiarities of type G have attracted some degree of attention. B. Boss (*Astron. Journ.*, Nos. 649–50) finds that they tend to favour the vertex of the second drift in the proportion 3 : 2, practically reversing the proportion found for the remaining stars.

Distribution of the Stars.—The distribution of the stars which are brighter than a limiting magnitude as regards distance has been investigated by essentially similar methods by F. W. Dyson and A. S. Eddington (*Monthly Notices*, lxxiii. pp. 334, 346 and 402). Both authors have found that the number of stars between the

distances r and $r+dr$ can be expressed by the formula $re^{-h^2r^2}$ with considerable accuracy. Dyson's data consisted of 3735 stars within 9° of the pole reaching down to the B.D. limits of magnitude; Eddington's data referred to stars brighter than magnitude 5·8 in selected regions of the sky, types A and K being treated separately. Tables are given in the papers showing the proportion of stars (brighter than the magnitude considered) within various limits of distance. The main features are the large proportion contained within a comparatively small range of distance; thus Dyson found that, of stars brighter than $10^m{\cdot}3$, 70 per cent. have parallaxes between ·″0050 and ·″0015; of the stars brighter than $5{\cdot}8^m$, treated by Eddington, 75 per cent. are included between parallaxes ·″020 and ·″004.

H. Seeliger (*Sitzungsberichte d. K. Bayerische Akad. München*, 1912) has continued his researches on the distribution of the stars. His latest results exhibit the spheroidal distribution of the stars by comparing for different galactic latitudes the rate at which the density thins out with increasing distance.

C. Easton (*Astrophysical Journal*, **37**, p. 105) has produced a new drawing of the Milky Way, made by combining the available photographs. With this chart is given a hypothetical representation of the Galaxy as a spiral, carefully designed to take account of all the important features. The author's intention is only to indicate in a general way how the stellar accumulations might be arranged so as to produce the phenomenon of the Milky Way, without claiming that it is a unique solution; but his figure is very instructive, showing how the spiral theory works out in detail. We may add that the second edition of the plate, circulated with the reprints, is superior to the plate first published.

Stellar Dynamics.—There appears to be conclusive evidence that the motions of the stars are not appreciably disturbed by the approaches of neighbouring stars, and that in considering their orbits during the course of long periods of time we need only take into account the general or central attraction of the whole system. The most direct evidence for this is the continued existence of moving clusters, for, if the casual encounters of stars had an appreciable effect, these could not remain undissolved. J. H. Jeans (*Monthly Notices*, lxxiv. p. 109) has investigated the influence of the encounters analytically. Taking a reasonable estimate of the density of distribution of the stars, he finds that the probable deflection of path due to encounters would amount to 1° only after 3×10^9 years. The insignificance of the encounter-effects renders the problem of stellar dynamics entirely different from gas dynamics; the stellar universe cannot have approached anywhere near the ultimate state considered in the kinetic theory of gases. Adopting the same basis, A. S. Eddington (*Monthly Notices*, lxxiv. p. 5) has investigated some of the simpler types of possible stellar systems, especially with a reference to H. H. Turner's suggested explanation of the two star-streams referred to in last year's Note. A. S. E.

The "Plan of Selected Areas."

The plan of selected areas worked out and published in 1906 is a plan which may be realised by the co-operation of a few astronomers in a, relatively speaking, moderate time. The aim of it is to bring together, as far as is possible with such an effort, all the elements which at the present time must seem necessary for a successful attack on the sidereal problem—that is, the problem of the structure of the sidereal world.*

The considerations that led to the exact form which the plan finally took are evident enough. Data are obviously required for the faint stars as well as for the bright ones. For the fainter stars, however, the collection of all the elements (position, proper motion, parallax, magnitude, spectrum, radial velocity, etc.) complete for the whole of the sky is of course out of the question. One must be content with specimens representative of the whole, therefore with areas well distributed over the sky. As most of the questions to be investigated relate to the way in which the several elements depend on each other—questions such as: What is the mean parallax of the stars of a given magnitude or a given P.M.? what connection is there between spectrum and P.M.? what between spectrum and radial velocity? and so on—these areas must evidently be the same for all, so that for a representative set of stars *all* the elements obtainable with the means at present available must be collected.

The plan contains: (*a*) 206 regions of which the centres are regularly distributed all over the sky (*systematic plan*); (*b*) special plan containing 46 additional regions—regions extremely rich or extremely poor in stars, or at least regions to which some special interest is attached.

The following remarks give a rapid summary of what is already accomplished, and what is going forward in the several subdivisions of the work.

1. *Durchmusterung.*—For the Southern sky photographs with an exposure of 2 hours have been taken at Arequipa with the Bruce refractor (24-inch). For the Northern sky there is a *double* series: the first, obtained with the 16-inch Metcalf telescope at Harvard, exposure 1 hour; the second, taken with the 60-inch reflector on Mount Wilson, exposure 1 hour.

The Arequipa and Harvard series for the *systematic* plan have been completely measured at Groningen with the exception of a few plates that either could not yet be obtained or must be repeated. Areas have been measured, covering $80' \times 80'$ between galactic latitudes ± 40 to ± 90; $60' \times 60'$ between galactic latitudes ± 20 to ± 40; $40' \times 40'$ between -20 and $+20$. The limiting magnitude for the Southern Hemisphere is about 17th magnitude

* *Plan of Selected Areas*, p. 1.

(scale of polar sequence); for the Northern about 16th. The probable error in position will be about $\pm 1''$ for each co-ordinate, that in magnitude about $\pm 0^{m}\cdot 1$.

Plates for the special plan have also been taken at Arequipa and Harvard. For the Northern Hemisphere the measurement at Groningen is also finished. The Southern plates will be undertaken shortly.

The reductions are far advanced. The only remaining difficulty is with the magnitudes. They must wait till the standards are available (see next paragraph). The work will appear in the *Annals* of the Harvard Observatory.

The Mount Wilson plates have been completed, and are now at Groningen for measurement. They ought to furnish for an area of $10' \times 10'$, or somewhat more, all the stars down to at least 18th magnitude.

2. *Photographic Magnitudes.* — For the reduction of the Arequipa and Harvard plates, Professor Pickering provides a sequence of about 15 standards down to 14^{m} or 15^{m} for each plate on the scale of the polar sequence. The determinations are already finished for a good number of the fields.

Professor Seares is determining with the 60-inch, for a field $23'$ in diameter, the magnitude of all the stars down to about magnitude $17\cdot 5$, on an absolute scale, the zero point of which will be determined by inter-comparison and by comparison with the polar sequence.

For the Southern Hemisphere the Observatory at Johannesburg has undertaken a comparison of the magnitudes of each of the Southern areas with those of the four Harvard standard areas at $+15^{\circ}$, 1^{h}, 7^{h}, 13^{h}, 19^{h}, (Equinox 1900).

At Greenwich magnitude determinations are being made in connection with the countings on the Franklin-Adams plates. The determinations have been courteously arranged in such a manner that the selected areas may be benefited. These areas are only concerned with the comparisons which are being made with Pickering's polar sequence. They are obtained by photographing with the 26-inch refractor the sequence on the same plate with each of the areas. Up to the present, 22 of the selected areas have been obtained according to the scheme: Pole $6^{min}\cdot$, Field $6^{min}\cdot$, Field $6^{min}\cdot$, Pole 6^{min}. They will yield the magnitudes down to about 13th magnitude.

For prolonging the scale to the fainter magnitudes of the Franklin-Adams plates, another series of plates is being taken with the 26-inch refractor which will not only serve the purpose for which it was introduced, but which may eventually help to strengthen the absolute scale of magnitudes.

In Potsdam the magnitudes for the 24 areas of the systematic plan in declination $+15^{\circ}$, *eight* regions of the special plan, and the *ten* Pritchard-Kapteyn areas are being determined. Three exposures of 90 minutes each have been made with the large refractor, and three with the Zeiss-Triplet. The method followed

is the *Hulbgitter* method.* The plates have been completed. The results obtained with the Zeiss-Triplet will be shortly published. For the great refractor plates the zero of the scale has yet to be fixed.

The Observatory of Minneapolis has volunteered to contribute by comparing the several areas of the Northern sky with the polar sequence.

It seems desirable not to delay the publication of the Durchmusterung till all these materials for magnitude are available, but to bring it out as soon as fairly reliable results can be obtained. Even if we waited for the completion of all the work now in hand, the system would not be blameless; as with the fundamental positions of the stars, the fundamental magnitudes will doubtlessly only be slowly and gradually brought to perfection.

3. *Visual and Photo-visual Magnitudes.*—In the Observatory of Pulkovo a determination of the visual magnitudes for zone $+15°$ (systematic plan) has been made by Mr. Okoulitch with the 15-inch refractor. The observations are complete, with the exception of the two areas No. 85 and 86, which cannot be satisfactorily observed during the summer on account of twilight. Observations of the Pleiades are now being made, in order to obtain the reductions to the Harvard scale.

A complete determination of the magnitudes on red sensitive plates with suitable filter is contemplated by Professor Seares on Mount Wilson, using for the purpose the 60-inch telescope.

The excellent results for the effective wave-lengths of the faint stars, recently obtained by Professor Hertzsprung (not yet published) suggest the desirability of a complete set of determinations according to this method.

4. *Parallaxes.*—For the Southern sky parallax plates were made with the astrographic telescope of the Cape Observatory. The plates were all but complete at the beginning of 1911. Measurement has been begun at Copenhagen under the direction of Professor Strömgren.

For the Northern sky the several zones have been undertaken by the following observatories: Evanston (0°); Nicolaiev (+15°); Allegheny (+30°); Williams Bay (+45°); Greenwich (+75° and +90°). The apertures of the refractors are respectively 19, 32, 30, 40, and 26 inches. At Evanston the work has just been begun. At the Yerkes Observatory 36 plates out of a total of 96 had been obtained up to September last. Some of these, however, must be repeated. At Greenwich a number of plates have been taken, but some are valueless through a defective mounting of the 26-inch object-glass. After the defect had been put right, some more plates were taken. Those of the polar area will very shortly be measured.

At the Observatories of Nicolaiev and Allegheny the work has

* For an explanation of the method see *Monthly Notices*, vol. lxxiii. pp. 294–295.

not yet been begun, because the instruments are not yet fully completed.

The enormous superiority of the long-focus instruments over the shorter ones, for purposes of parallax, is becoming more and more manifest. Whether reflectors can compete with refractors for such work is still more or less uncertain. Some preliminary experiments at the 80-foot focus of the Mount Wilson 60-inch reflector promise extremely well. If this promise is fulfilled, the great advantage would be gained that very faint stars can be included over a field which is at least moderately extensive.

It is very gratifying that in the Northern Hemisphere all the participating instruments are long-focus instruments. The only drawback is that the usually somewhat limited field will make it desirable to have more than one set of plates for each area. There thus is good occasion for further co-operation.

Both at the Yerkes and Evanston Observatories the telescopes are visual and a light filter has to be used before the plate. It appears that the accuracy suffers little or nothing from this cause. The images are excellent, probably better than could be obtained without a filter with a photographic telescope. The question thus arises whether even in these latter telescopes the quality of the images could not be very materially improved by the introduction of a suitable filter.

It would be exceedingly desirable to have one or more long-focus instruments taking part in the work for the Southern sky.

5. *Proper Motions.*—For the Southern sky it is the intention to have a new series of parallax plates taken with the astrographic telescope at the Cape Observatory at some future epoch. These together with the already existing parallax plates will furnish excellent data for P.M.

For the Northern Hemisphere the P.M. plates were undertaken by the Radcliffe Observatory with the 24-inch refractor. 136 regions are on the programme (systematic plan for the declination 0° to + 90° and 21 special areas). For each region two plates of 30 minutes' exposure are taken. One of them is stored away undeveloped; it will only be developed after exposure at a later epoch. Of the 272 plates thus required for the whole plan (early epoch) 148 were finished last June; some more were taken but were put on the list for repetition.

6. *Standard Proper Motions.*—For these we must employ stars of which the P.M. can be derived from older meridian observations, especially those in the *Astronomische Gesellschaft* Catalogue combined with modern determinations. A series of the latter have been promised by Professor Küstner. They can probably be begun with the meridian circle at Bonn in 1916.

These observations will no doubt be in general so much superior to the older observations that at present nothing material for the P.M. will be gained by further meridian observations at

other observatories. In future, however, after the lapse of fifty or one hundred years, it will of course be of the greatest importance to have early determinations of position of high precision. In the opinion of several astronomers it would be important for this reason to have several observatories taking part in the determination of position for the present epoch. Professor Küstner expresses himself as follows: "I think it not only desirable, but altogether necessary that the standard P.M. stars be observed not only at one but at several observatories. For only in this way will it be possible to find out the systematic errors of observations. On the other hand, it will not be necessary for any of the separate observatories to make a great number of observations."

7. *Additional Proper Motion Plates for the Parallels of* $-45°$ *and* $+45°$.—As the completion of the P.M. plates will necessarily take a long time, a series of 23 regions at $+45°$ and 24 regions at $-45°$ have been selected, for which good old plates were available either at Helsingfors or at the Cape. These have been recently repeated. The average differences of epoch are respectively about 11 years and 16 years. Of the first series 8 pairs have been measured and reduced at Groningen. The P.M. will shortly be published. The rest of the Northern plates will be measured and discussed at Vassar College. For the Southern plates the measurement had been undertaken by Professor Jacoby. As it turned out, however, that it would be impossible for him to have the work done at the Columbia University, the plates are now being measured at Groningen.

8. *Spectra.*—The revised Draper Catalogue, at present so energetically pushed forward at Harvard Observatory, will provide for the spectral classification down to about the 9th magnitude. It remains a desideratum—one of the most urgent of the whole plan—to have the limit brought down another couple of magnitudes for the regions covered by the selected areas.

9. *Radial Velocities.*—As the number of bright stars in the selected areas is so small, contributions may only be hoped for from the most powerful instruments. The stars brighter than 8·0 have been placed on the programme of the 60-inch telescope at Mount Wilson. Provisionally, however, it is the intention to give precedence to other even more pressing work. Rapid progress must, therefore, not be expected, perhaps not before the completion of the 100-inch telescope.

10. *Brightness of the Background of the Sky.*—A few observations have been made at Groningen by Dr. Yutema and on the top of Mount Whitney by Professor Abbot. A much more extensive series has now been completed at Mount Wilson by Mr. van Rhyn, student of astronomy at Groningen. J. C. K.

Astrographic Chart and Catalogue.

It is not possible to give a tabular statement of the exact state of the Astrographic work at the co-operating observatories, but reference to the corresponding Report of last year will show that publication of the zones of the Catalogue which cover the sky from the North Pole to 2° S. declination is complete or is proceeding. Vol. iv. part i. of the Catania Catalogue, covering the first 3 hours of R.A. of zone 50° N. is to be added to last year's record. The plates of the zone 64° to 55° N., allotted to the Vatican Observatory, which are taken and measured in Rome, are being reduced and prepared for press under the superintendence of Professor Turner at the University Observatory, Oxford. A portion of this zone is ready for publication. With the exception of the zone 17° to 23°, the southern hemisphere is shared between the observatories of San Fernando (Spain), Tacubaya, Cordoba, Perth (W. Australia), Cape of Good Hope, Sydney, and Melbourne. The two observatories first named are making and distributing enlarged reproductions of chart plates and measuring and reducing those of shorter exposure, but as yet have made no contributions to the Catalogue. No report from the Cordoba Observatory is available, but doubtless Dr. Perrine is proceeding with his share of the undertaking. The plates of the zone 32° to 40°, taken at the Perth Observatory, are being measured at the Royal Observatory, Edinburgh, and two parts of the Perth Astrographic Catalogue published in 1913 contain the measures of 41,200 star-images on 80 plates to be added to the 80 reported last year. The total number of plates in this zone is 1376. The printing of the measures of the zone 41° to 51°, which is in the hands of the Cape Observatory, has been begun. The cap which covers the sphere from the limits of this zone to the South Pole is shared between the Sydney and Melbourne Observatories, and though the measurement and reduction of the plates taken at these observatories has been proceeding for some years, no publication has yet been made. The zone 17° S. to 23° S. was allotted originally to the Santiago Observatory, and was afterwards offered to an observatory that it was proposed to erect in Monte Video; but in 1909 it was resolved by the Permanent Committee that the work of this zone should be shared by three observatories, who were willing to take part in the scheme. There is some information that this has been begun.

Two Bulletins have been issued by the Permanent Committee. The first (tome vi. fasc. i.) is almost entirely filled with the Photographic Catalogue of stars observed with the planet Eros, compiled by Mr. Hinks, and used by him in his determination of the Solar Parallax. The catalogue is given in the form of a star-ledger, and is preceded by an introduction giving complete details relating to the work. This fascicule contains also a memoir on Astronomical Refraction by M. Esclangon of Bordeaux, and a short report by the committee appointed to consider the question of Photographic Magnitudes.

The second Bulletin (tome vii. fasc. 1) consists of the list of *Intermediary* stars for the northern hemisphere selected by Professor Küstner in accordance with the proposed scheme for making a fundamental catalogue of stars by meridian observation which shall serve as the basis or framework for photographic catalogues.

A catalogue of 3700 stars to be used as reference stars for the reduction of the Algiers Zone of the Astrographic Catalogue (4° N. to 2° S. Dec.), formed from observations with the Transit-circle of the d'Abbadia Observatory, has been published in 1913.

Volume viii. part i. of the Oxford Astrographic Catalogue—Corrections to the places of the Cambridge (Astr. Gesell.) Catalogue deduced from Oxford photographic measures—has also been published. The general contents are explained by the sub-title, but the part, as might be expected, contains some information on Proper Motion and magnitude equation.

The following table shows the total number of enlarged reproductions of chart plates distributed by different observatories up to the end of 1913. The French observatories are issuing reproductions of alternate zones only.

Algiers . . .	449	Rome . .	44
Bordeaux . .	236	San Fernando .	406
Brussels . .	39	Tacubaya .	323
Paris . . .	470	Toulouse .	288

Of the 44 charts issued by the Vatican Observatory, Rome, the 11 most recent have been reproduced by a heliogravure process, similar to that used for the charts of the French observatories.

H. P. H.

Series Lines in Spectra.

In view of recent investigations of spectral series in relation to astrophysical spectra, it may be useful to summarise briefly the main facts relating to this subject. In many spectra the lines have the appearance of being distributed at random, but in others there are lines which succeed each other with great regularity, so that their positions may be represented by formulæ. In such a *series*, the lines become closer, and the intensities degrade, in passing from red to violet, and in nearly all cases several series coexist in the same spectrum. The simplest example is afforded by hydrogen, of which the lines ordinarily observed were shown by Balmer to be connected by the formula

$$\text{wave-length} = \lambda = 3646{\cdot}14\,\frac{m^2}{m^2-4}$$

where m takes successive integer values. For several reasons it is more profitable, as a rule, to deal with wave-numbers ("oscillation frequencies") rather than with wave-lengths, the wave-number being $10^8/\lambda$, or the number of waves per centimetre. For greater accuracy, these numbers are corrected to vacuum with the aid of

data for the refractive index of air. In wave-numbers (n), and in general terms, Balmer's formula becomes

$$n = n_\infty - \frac{4n_\infty}{m^2}$$

where n_∞ is the *limit*, or end, of the series, corresponding to $m = \infty$.

Numerically, the formula for hydrogen, which represents the lines with extraordinary accuracy, is

$$n = 27418{\cdot}75 - \frac{109{,}675}{m^2}.$$

The number 109,675 appears in the formulæ for other series and is called the "universal constant"; it is often represented by N.

The work of Rydberg, and that of Kayser and Runge, showed the existence of a great number of such series. In the general case, three associated series were found in the same spectrum; namely, in order of intensity, the Principal, Diffuse (or 1st subordinate), and Sharp (or 2nd subordinate) series, the names for which are conveniently abbreviated to P, D, and S. The limits of the series are sometimes indicated by P∞, D∞, S∞ respectively.

The generalised form of the Balmer formula was found to be inapplicable to series as a whole, and Rydberg employed, with great effect, the modification

$$n = n_\infty - \frac{\mathrm{N}}{(m+\mu)^2}$$

where N is the universal constant derived from hydrogen, and μ is an additional constant which has usually a fractional value special to each series. n_∞ and μ can of course be determined from the wave-numbers of observed lines. Kayser and Runge's formula was somewhat different, but either of the formulæ showed that the limits of the D and S series were probably identical. Rydberg found further important relations between the P and S series; namely (1) that the difference between the limit of P and the common limit of the D and S series was identical with the wave-number of the first P line;* (2) that when m is put equal to unity in the formula for the S series the wave-number of the first P line is obtained with negative sign.

The limit of a series can obviously also be expressed in the form $\mathrm{N}/(m+\mu)^2$, and Rydberg embodied the above relations in the set of equations:

P series	$\mathrm{P}(m) = \frac{\mathrm{N}}{(1+s)^2} - \frac{\mathrm{N}}{(m+p)^2}$	$m = 1, 2, 3 \ldots$
S series . .	$\mathrm{S}(m) = \frac{\mathrm{N}}{(1+p)^2} - \frac{\mathrm{N}}{(m+s)^2}$	$m = 2, 3, 4 \ldots$
D series . .	$\mathrm{D}(m) = \frac{\mathrm{N}}{(1+p)^2} - \frac{\mathrm{N}}{(m+d)^2}$	$m = 2, 3, 4 \ldots$

* This was discovered independently by Schuster, and is often called the Rydberg-Schuster law.

where p, s, d represent the values of μ in the respective series. Although the Rydberg formulæ fail in most cases to represent series within observational limits of error, there is reason to believe that the above relations are strictly true.

A more accurate representation is given by the formulæ due to Ritz, namely,

$$n = A - \frac{N}{\left(m + \alpha + \frac{\beta}{m^2}\right)^2}; \text{ or } n = A - \frac{N}{[m + \alpha + \beta(A - n)]^2}$$

where A (the limit), α, and β are constants which can be determined from three observed lines. In the P and D series, m takes integral values, but in S it is to be put $= 2{\cdot}5, 3{\cdot}5$, etc.

Experience has shown that series are still more accurately represented by the Hicks formula

$$n = A - \frac{N}{\left(m + \alpha + \frac{\beta}{m}\right)^2}$$

where m has integral values throughout.

For a system of series, these equations may be written in the Rydberg form given above, α and β being replaced by p, π for the P; d, δ for the D; and s, σ for the S series. For convenience in writing, Ritz suggested the abbreviation $m\alpha\beta$ for the variable part of the general equation, which becomes $mp\pi$ for the P, $md\delta$ for the D, and $ms\sigma$ for the S series. Paschen has adopted the still shorter forms mp, md, ms; and $3p$, for example, is to be understood to mean $N/(3 + p + \frac{\pi}{3})^2$ if the Hicks equation be employed.

An ordinary system of three associated series of single lines (with the Rydberg numeration of the lines) may thus be expressed by

$$P(m) = 1s - mp.$$
$$S(m) = 1p - ms.$$
$$D(m) = 1p - md.$$

Each component of a series may be a doublet or a triplet, the members of which are sometimes very close, and sometimes far apart. In these systems the components of the D and S series, and of the first member of P, have the same wave-number separations, but the components of P converge to the same limit and therefore become closer as the limit is approached. To take a doublet system as an example, the symbolic representation, with the same numeration of the lines as before, is as follows:—

$P_1(m) = 1s - mp_1$. Shorter wave-length.
$P_2(m) = 1s - mp_2$. Longer ,,

$S_1(m) = 1p_1 - ms$. Longer ,,
$S_2(m) = 1p_2 - ms$. Shorter ,,

$D_1(m) = 1p_1 - md$. Longer ,,
$D_2(m) = 1p_2 - md$. Shorter ,,

These equations embody all the relations of the three associated series. With the Ritz numeration, the terms $1s$ and $1p$ are to be replaced by $1{\cdot}5s$ and $2p$ respectively. In the cases of triplets the additional terms mp_3 and $1p_3$ have to be introduced.

Systems of single lines, doublets, and triplets sometimes occur in the same spectrum, and it should be noted that in elements of the same chemical group the doublet or triplet separations are roughly proportional to the squares of the atomic weights. Also that the limits of corresponding series advance towards the red as the atomic weight increases.

Series lines are frequently further complicated by the presence of satellites associated with the less refrangible components of the D series. In a doublet system there is only one satellite to each of the less refrangible components of the D lines, and it is the satellite which obeys the law of constant frequency difference in association with the more refrangible components; the chief lines, however, gradually approach the satellites in passing along the series, and have the same limit. The formulæ for the P and S series are unchanged, but the D formulæ become

$$D'(m) = 1p_1 - md' \text{ (satellite).}$$
$$D_1(m) = 1p_1 - md \text{ (1st chief line, longer wave-length).}$$
$$D_2(m) = 1p_2 - md' \text{ (2nd chief line, shorter wave-length).}$$

In the case of triplets, the least refrangible components have two satellites, the middle lines one, and the third none at all.

It will be observed that the wave-number of a line always appears as the difference of two other wave-numbers, one of which is the limit of the series of which it forms a part. As first shown by Ritz, lines are often found in positions corresponding to differences between wave-numbers taken from the same or different series. This is the "combination principle" of Ritz, which has been firmly established by the extensive observations made by Paschen in the infra-red and other regions of the spectrum. Thus, one may find a line corresponding to the combination $2p - 4s$, or a series $3d - mp$, and so on.

Paschen has shown that the combination principle can be proved independently of a knowledge of an exact series formula. A calculated limit being adopted for one of the series, the limits of the associated series are deduced from observed lines by the Rydberg laws (when the observations are sufficiently complete), and the variable terms mp, etc., can then be derived by subtracting the wave-numbers of the observed lines from the limits of the series to which they belong. However erroneous the first adopted limit may be, the others are affected by the same amount, and the errors disappear when taking differences in forming the various combinations. Paschen and his pupils have thus identified an immense number of combination lines and series, and the accuracy with which they are represented is conclusive evidence of the truth of the Rydberg relations.

One type of combination series is of such importance that it

should perhaps rank as a fourth chief type in company with the P, S, and D series. These series, which often include very bright lines, long escaped observation because of their occurrence principally in the infra-red. They were first observed by Bergmann in that region, but have since been recognised in other parts of the spectrum, including the "Schumann" region in the extreme ultra-violet. These series are commonly known as "Bergmann series," but the name "Fundamental," or F series, assigned by Hicks, is also often given to them. Runge first pointed out that the limit of the F series is given by the difference between the common limit of the D and S series and the wave-number of the first D line; that is, $F\infty = D\infty - D(2)$, or $F\infty = 2d$.

For the complete representation of the F series, Ritz suggested the combination

$$F(m) = 2d - m\Delta p$$

where $\Delta p = p_1 - p_2$; or more fully,

$$m\Delta p = \frac{N}{\left[m + (p_1 - p_2) + \frac{(\pi_1 - \pi_2)}{m}\right]^2}.$$

This gives a useful approximation, but is not exact, and the precise connection with the P series is not yet clear.

When there are no satellites, the F series consists of single lines, as the term $2d$ has then only one value, either in the case of doublets or triplets. In doublet systems in which satellites occur, there is the term $2d'$ as well as $2d$, and the F lines are equidistant doublets having a separation equal to that of the satellite and chief line in the first member of the D series. In the F series of a triplet system having satellites, the lines are triplets with separations equal to those of the two satellites and chief line in the first member of the first D triplet.

In a fully observed system of series, the terms $m\Delta p$ can always be determined from the known value of $2d$ and the wave-numbers of the observed lines. It is then often found that the values so determined can be associated with terms from other series to form additional combinations, which agree with lines actually observed.

The application of the combination principle has shown that many lines which had previously appeared to be unattached really form part of the general series scheme, and it is possible that in spectra like that of iron, in which no series have yet been traced, the complexity is due to the existence of a great number of combinations.

The theory of atomic vibrations is not yet sufficiently developed to explain the more complex systems of series, but attempts have been made to derive formulæ for the simple series of hydrogen, and for the possibly simple systems of lines occurring in the spectra of nebulæ, Wolf-Rayet stars, and the solar corona.

Among the more recent experimental and theoretical investigations, the following may be mentioned.

A number of lines near the positions calculated by Rydberg for the hypothetical P and S series of hydrogen have been produced by Fowler by passing strong discharges through helium tubes having hydrogen impurity (*M.N.*, vol. lxxiii. p. 62). From theoretical considerations, however, Dr. Bohr has since concluded that these lines are due to helium.

R. Rossi (*Phil. Mag.*, Dec. 1913) has recently detected series, which are expressed by a Rydberg's formula, in the spectrum of Neon, viz. two series of doublets which run nearly parallel to the lines of the hydrogen spectrum. The principal series could not be found, but a series of ultra-violet lines was found experimentally. These series are specially interesting in that they do not correspond to the helium subordinate series, for the approximate relation between the separation of the doublets and the squares of the atomic weights does not hold.

W. M. Hicks (*Roy. Soc. Proc.*, A, lxxxix., 1913; *Phil. Trans.*, A, vol. 213) has continued his previous work on the more exact representation of spectral series by formulæ, proceeding to a discussion of the "atomic weight" term whose existence in the formulæ has been suggested. If the series formula, expressed in wave-numbers, is put into the form

$$n = \mathrm{N}(\mathrm{D}_1^{-2} - \mathrm{D}_m^{-2})$$

where D_m is a function of an integer m, and N is Rydberg's constant, then the constant triplet (or perhaps doublet) separations of Diffuse and Sharp series are formed by deducting quantities Δ_1, Δ_2 from D_1, such quantities being roughly as the squares of the atomic weights. Hicks introduces a new physical quantity, the *oun*, which he regards as fundamental in the series formulæ for the spectrum of any element. If w is the atomic weight, divided by 100, its value is $(90{\cdot}4725 \pm 0{\cdot}0013)\ w^2$, and evidence of its existence appears to be derived from the spectra of very diverse elements. The main conclusions of the paper are:—

(1) The quantities Δ giving the doublet and triplet separations are all mutliples of the *oun*.
(2) The corresponding quantities giving the satellite separations in the Diffuse series are multiples of the *oun*.
(3) The F series show satellites depending on the *oun*.
(4) Lines may be collaterally displaced—*i.e.* instead of an expected line there is one following another series differing only by a multiple of the *oun* in its denominator.

It is suggested also that the Diffuse series may not in reality follow a formula involving an integer m.

N. Bohr (*Phil. Mag.*, July, Sept. 1913) has given a remarkable theory of the hydrogen spectrum, which has led to a considerable amount of discussion. We shall consider only the portion which is of astrophysical interest. Its main basis is the law of Planck and the angular momentum principle used by Nicholson in connection with the coronal spectrum. Hydrogen is regarded as having an atom consisting of one electron rotating about a nucleus of equal

positive charge, with angular momentum which can be any multiple of $h/2\pi$, where h is Planck's constant, but which will in the normal case be $h/2\pi$ exactly. These possibilities are known as *steady states*, and series spectra arise by passages of the atom from one state to another. When the angular momentum is $\tau h/2\pi$ the energy radiated out in the collection of the atom from infinite dispersion to this state is

$$W = \frac{2\pi^2 me^4}{\tau^2 h^2}$$

where m and e are the mass and charge of an electron. In passing from state τ_1 to state τ_2 the energy emitted is

$$W = \frac{2\pi^2 me^4}{h^2}\left(\frac{1}{\tau_1^2} - \frac{1}{\tau_2^2}\right),$$

which Bohr regards as a *homogeneous* radiation, and therefore of a frequency ν given by Planck's formula $W = h\nu$. We thus obtain

$$\nu = B\left(\frac{1}{\tau_1^2} - \frac{1}{\tau_2^2}\right)$$

where τ_1 and τ_2 are integers, and B is found to agree very closely with the experimental constant of the hydrogen spectrum. This includes the Balmer series, and the Ritz series in the infra-red spectrum of hydrogen, but not Fowler's new series or the Pickering series. These, however, can be interpreted as due to helium, if we suppose that a neutral helium atom consists similarly of two electrons rotating round a nucleus of charge $2e$ with the same possible values of the angular momentum. If one electron is removed, the charged atom is shown to give a series

$$\nu = B\left(\frac{1}{(\tau_1/2)^2} - \frac{1}{(\tau_2/2)^2}\right),$$

including not only the series mentioned above, but also Balmer's series. A recent discussion in *Nature*, however, indicates that it is a slightly displaced Balmer's series, which should be capable of being distinguished from the Hydrogen series on good plates.

This theory has not, as yet, given the ordinary helium spectrum, but it has been worked out further on its physical and chemical sides, and, moreover, it gives a ready reason for the existence of Rydberg's constant N for series spectra.

Some lines in the Wolf-Rayet stars, forming the series

$$\lambda = 3647\frac{(m \pm \frac{1}{2})^2}{(m \pm \frac{1}{2})^2 - 4}$$

were suggested by J. W. Nicholson (*Monthly Notices*, Feb. 1913) as a new Hydrogen series. Bohr's work ascribes these lines to lithium with a double positive charge.

J. W. Nicholson (*M.N., R.A.S.*, Dec. 1913), has suggested that the lines of unknown origin in Wolf-Rayet stars are the

leading members of a set of series analogous in form to Balmer's formula, but different in that they do not preserve Rydberg's constant N. The series contain an integer n which gives them a set of limits of constant frequency difference, and the constants are theoretically calculable from those of the hypothetical atom of nebulium, previously treated as a component of nebulæ. It is suggested that there is evidence of a progressive evolution in early stars which can be traced through the spectra, the increase of the constant n being co-ordinate with an increase of complexity of the internal structure of the atom.

A. F.
J. W. N.

Stellar Spectroscopy in 1913.

Nebulæ and Wolf-Rayet Stars.—The spectra of spiral nebulæ and globular star clusters (*N.G.C.*, 1023, 3031, 4594, 4736, 4826, 5194, 7331) have been studied by Mr. E. A. Fath at Mount Wilson (*Ap. J.*, **37**, 198) in continuation, with a more powerful spectrograph, of his earlier work (*Ap. J.*, **33**, 58). His work shows that in the case of 12 globular clusters the brighter stars have spectra ranging only from the F- to the G-type. In the case of 11 nebulæ examined, of which 9 are certainly spiral, the spectra are of G- or K-type: but in 2 cases the spectra are peculiar, in exhibiting the bright lines connected either with gaseous nebulæ or with Wolf-Rayet stars. The simultaneous occurrence of absorption lines and emission lines has also been found by Dr. Max Wolf, who has specially studied the spectra of such nebulæ, and confirms the earlier observations of Huggins with respect to the existence of bright lines in the spectrum of the Andromeda nebula.

The radial velocity of the Andromeda nebula has been determined by V. M. Slipher at the Lowell Observatory (*Bull.*, No. 58), with a result −300 km/sec as the mean of 4 determinations. The same writer finds (*Bull.*, No. 57) that the spectrum of the Pleiades nebula appears to be continuous, exhibiting no gaseous lines.

Dr. Wolf has found certain nebular lines in the spectrum of one of the Wolf-Rayet stars, B.D. 30°·3639 (*Sitz. Heid. Akad.*, 1913, No. 14). In this same Wolf-Rayet star two red lines at λλ 6548, and 6583 as strong as H_α have been found by P. W. Merrill (*L.O.B.*, vii. p. 129); they have been found by Wright in the planetary nebula, *N.G.C.*, 7027, but are otherwise unidentified. Dr. Wolf has also got (*loc. cit.*) the spectra of three other Wolf-Rayet stars, B.D. 35°·4001, 35°·4013, and 36°·3956, and finds therein considerable differences. In another communication (*Sitz. Heid. Akad.*, 1913, No. 22) he gives the results of his study of the Wolf-Rayet stars, B.D. 37°·3821 and 35°·4001. In both stars he finds a strong emission line at λ 3483 and a marked absorption line at λ 3868.

A remarkable paper by J. W. Nicholson (*M.N.*, **74**, 118) deals with the mathematical analysis of the spectra of Wolf-Rayet stars. In it the author gives an entirely new approach to views held by astrophysicists that Wolf-Rayet stars are the earliest products of some form of evolution from primitive nebulæ. The evidence adduced is extraordinarily vividly set forth in the paper, and it is hardly possible to indicate in a few lines of summary the feeling of cogency conveyed by the accumulative argument. The suggestive power of the treatment leads one to anticipate from it a development as great in the interpretation of the physics of spectra in general as in support of astrophysical views of the place of Wolf-Rayet stars in celestial evolution.

Novæ.—The telescopic appearance of several temporary stars has been studied by Professor Barnard (*Ast. Nach.*, **194**, 401, and **196**, 167).

The following references serve as a guide to information about the spectrum of Nova Geminorum No. 2, which was discovered by Enebo on 1912 March 12 :—

Küstner,	*Ast. Nach.*, **194**, 369,	Narrow absorption lines.
Brill,	,, **194**, 409,	Brightness of the nebular line 469.
Jordan,	*Allegheny Pubns.*, iii. 17,	Preliminary study of 18 spectrograms.
Newall & Stratton,	*M.N.*, **73**, 380,	Enhanced lines in early spectrum.
Cortie,	,, **73**, 646,	Spectrum 1912 April and 1913 Feb.–April.
Adams & Lasby,	,, **73**, 742,	Later spectrum.
Max Wolf,	*Sitz. Heid.*, 1913, No. 9,	Later spectrum 1913 March.
Furuhjelm,	*Potsdam Obs.*, xxii., No. 68,	Completed discussion of 11 spectrograms.
Belopolsky	*Mitt. Nic.*, v. 2, 1913, No. 50,	Early spectrum.
Tikhoff	,, ,, ,,	Objective-prism spectra.
Duffield,	*M.N.*, **73**, 631,	Pressure effect and Novæ.

The spectrum of P Cygni has been further studied by P. W. Merrill (*L.O.B.*, viii. 24) in continuation of earlier work (*ibid.*, vi. 156).

Studies of Special Stars.—The B stars with bright hydrogen lines have been made the subject of special study by P. W. Merrill (*L.O.B.*, vii. 162, and viii. 23). His results lead him to divide the stars observed into four groups, differing by the relative behaviour of the H_α, H_β, and H_γ lines: γ Cassiopeiæ group, b_2 Cygni group, Electra group, and ϕ Persei group.

The spectrum of ϕ Persei has been studied by F. C. Jordan (*Allegh. Obs.*, iii. 31); the complicated phenomena still leave much to be explained.

Bright reversals of the calcium lines H and K, such as are frequently observed not only in disturbed regions of the solar surface, but also in integrated sunlight, have been looked for in several stars by the Potsdam observers. In a note by K. Schwarzschild and G. Eberhard (*Ap. J.*, **38**, 292) the results of a search with an objective prism of UV glass are recorded; bright reversals have been found in *α Bootis*, *α Tauri*, *σ Geminorum*, but no such reversals were found in *α Aurigæ*, *α Ursæ Majoris*, *β Geminorum*, *α Orionis*, or *α Cassiopeiæ*.

The visual spectra of the brighter A stars have been studied by Miss Waterman (*L.O.B.*, viii. 1) by photographic methods in order to test how far the phenomena therein are of service for classification purposes. The paper contains also a beautifully concise tabular grouping of the stars of the Revised Harvard Photometry by spectral classes.

In a paper on a relation between the amplitude of brightness variation and the radial velocity of Cepheid variable stars, H. Ludendorff (*Ast. Nach.*, **193**, 301) points out a remarkable relation, viz., $2K = 47A$, where $2K$ is the velocity range in km/sec and A is the light range in magnitudes.

Certain lines in the spectrum of magnesium discovered by A. Fowler have been found in the spectrum of α Canis Majoris by F. E. Baxandall (*Proc. Camb. Phil. Soc.*, **17**, 323). The same author has given an interpretation of outstanding peculiarities in the spectrum of *α* Andromedæ, in identifying 16 lines with enhanced lines of manganese (*M.N.*, **74**, 250).

The variability of the spectroscopic binary *β* Cephei has been detected by P. Guthnick (*Ast. Nach.*, **196**, 357) by the application of Elster and Geitel's colloidal sodium and potassium cells. The star has the short period of $4^h{\cdot}6$, as determined by E. B. Frost (*Ap. J.*, **24**, 259). Dr. Guthnick's remarkable utilisation of the photo-electric effect has resulted in the detection of a variation of about $0{\cdot}1$ magnitude. The work has been carried out at Berlin-Babelsberg Observatory.

The Harvard College Observatory Circular No. 178 contains particulars of stars with peculiar spectra, including 10 stars with bright lines, and 19 stars with composite spectra.

Reference may be made to a useful summary on the problem of the Cepheid variables by D. Brunt (*Observatory*, 1913, p. 59).

K. F. Bottlinger (*Ast. Nach.*, **195**, 117) has measured with a microphotometer the intensity distribution within certain lines in the spectra of the following stars: *α Canis Majoris*, *α Cygni*, *δ* and *η Leonis*, *ζ Orionis*, *γ Cassiopeiæ*.

Classification and Distribution.—Two papers from the pen of H. Seeliger deal with spectral type, mean parallax and galactic latitude (*Ast. Nach.*, **193**, 161) and distribution of spectral types (*Ast. Nach.*, **194**, 137).

H. N. Russell gave an account of his recent studies of "giant" and "dwarf" stars in relation to their "absolute magnitudes," *i.e.*

the stellar magnitudes which they would appear to have if each star was brought to the standard distance of 32 light years (corresponding to a parallax of 0″·10). A résumé of his remarks is given in *The Observatory*, 1913, p. 324, and his fuller treatment will be looked for with interest. The work is an extension of his paper in *Proc. Amer. Phil. Soc.*, vol. **51**.

In a summary dealing with distribution of the spectral classes of stars, A. S. Eddington treats of related problems (*Observatory*, 1913, p. 467).

P. Stroobant (*C.R.*, **156**, 37) indicates the nature of the distribution of spectroscopic binaries.

Abetti (*Spett. Ital.*, 1913, p. 93) reviews the standpoint of the Harvard classification of stellar spectra on the eve of the meeting of the International Union for Solar Research, 1913.

The Harvard College Observatory Circular, No. 180, contains a list of the spectral type of 825 stars within 10° of the N. pole; it includes all stars having a magnitude of 8·3 or brighter in the Durchmusterung.

Radial Velocities.—The radial velocities of 915 stars of classes F, G, K, and M are published, "in the briefest possible form," by Professor Campbell in the *Lick Obs. Bull.*, vii. p. 113. This list, together with four others,

224 bright stars of Class B, *Lick Obs. Bull.*, vi. 108
212 ,, ,, ,, A ,, ,, vii. 20
100 ,, ,, of large proper motion, *Lick Obs. Bull.*, vii. 51
150 ,, ,, south of declination – 20°, *Publ. Lick Obs.*, ix. 329

puts at the disposal of astronomers the results obtained mainly at Mount Hamilton and Santiago, and relating to nearly 1600 stars brighter than 5·00 visual magnitude in the Revised Harvard Photometry, *Annals*, **50**.

Professor Campbell's Silliman Lectures, delivered in Yale University in the early part of the year 1910, have been published in book form with the title *Stellar Motions*, and all readers of the book will join in assuring the author that the hopes which he expressed at the end of his lectures, "that he has been able to furnish a glimpse into a surprisingly rich field of astronomical investigation," are amply fulfilled.

K. Schwarzschild (*Ast. Nach.*, **196**, 10) finds that from determinations of the velocities of six stars in Præsepe it seems probable that this cluster moves with a velocity similar in magnitude and direction to that of the Hyades.

A. Hnatek (*Ast. Nach.*, **195**, 171, and **196**, 389) has deduced, from measurements made with a single-prism spectrograph attached to the 15-inch Coudé of the Vienna Observatory, the velocities of 15 bright stars, mostly of type A. The same author has found that the star Groombridge 177 has a velocity +8·3 km/sec, and that it is not improbable that it belongs to the Taurus stream (*Ast. Nach.*, **195**, 311).

Spectroscopic Binary Stars.—Orbits are given for the following stars:—

				P.	e.
π_5 Orionis	Lee	*Ap. J.*	**38**, 175	3^d·700	0·00
ϵ Ursæ Majoris	Ludendorff	*Ast. Nach.*,	**195**, 369	4^y·15	0·31
63 Tauri	Jantzen	,,	**196**, 117	8^d·425	0·16
d Tauri	Wilson	*L.O.B.*,	vii. 104	3^d·57	0·0
113 Herculis	,,	,,	vii. 106	245^d·3	0·12
RR Lyræ	Kiess	,,	vii. 140	0^d·567	0·27
δ Cephei	Moore	,,	vii. 153	5^d·367	0·49
λ Tauri	Schlesinger	*Alleg. Obs.*,	iii. 23	3^d·953	0·05
R Canis Majoris	Jordan	,,	iii. 49	1^d·136	0·14
ζ Geminorum	Plummer	*M.N.*,	**73**, 661	10^d·154	0·23

The system of 9 Camelopardalis has been studied in detail by O. J. Lee (*Ap. J.*, **37**, 1). Adams and Frost had shown (*Ap. J.*, **19**, 350) that measures of the broad lines in its spectrum proved that it had variable radial velocity, and that it exhibited the peculiar behaviour of the sharp calcium line K similar to that detected by Hartmann in δ Orionis. Lee's recent work discloses phenomena which seem to suggest that the system consists of two stars of unequal mass embedded in an envelope of calcium vapour which, whilst relatively quiescent, is mainly drawn by the smaller component into two effective regions on each side of the primary.

The star B.D. – 1°·943 (Boss, 1349) is found by Z. Daniel (*Ast. Nach.*, **194**, 15) to be one of the stars enveloped by calcium. Adams showed that its velocity is variable (*Ap. J.*, **35**, 174). Daniel finds a range of velocity greater than 200 km/sec and a period of 3·05 days. He points out that it is within 1° of δ Orionis. E. Hertzsprung has detected variability in this star, B.D. – 1°·943. His observations show a variation of about one-third of a magnitude and a period comparable with Daniel's results.

Attention may here be called to a useful summary relating to "fixed calcium lines" by F. J. M. Stratton (*Observatory*, 1913, p. 366).

Variable velocity has been discovered in the double star 113 α Piscium by O. J. Lee (*Ap. J.*, **38**, 502). It appears that each component of the pair is a spectroscopic binary.

The star 4 Hev. Draconis is also found to be a spectroscopic binary. O. J. Lee's observations (*Ast. Nach.*, **194**, 415) show a range of 95 km/sec.

The star α Canum Venaticorum is found to exhibit many curious features. A. Belopolsky (*Ast. Nach.*, **195**, 159, and **194**, 1) called attention to alternating visibility and invisibility of certain lines in its spectrum, and by his later study it is made clear that it is a complicated system. F. Stratton gives (*Observatory*, 1913, p. 432) some account of the many peculiarities, and

F. E. Baxandall shows reason (*M.N.*, **74**, 32) for thinking that europium is present in the atmosphere of the star.

The light changes in α Orionis are recorded from 1901 to 1912 by C. P. Olivier (*Ast. Nach.*, **194**, 81), but it has not been possible to find any regularity in the light changes. It will be remembered that H. C. Plummer failed also to deduce any regularity in the variable radial velocity of this star (*Ast. Soc. Pac.*, **20**, 227).

The star 63 Tauri has been found to have variable radial velocity by K. Schwarzschild (*Ap. J.*, **38**, 295), who discovered the variability in a trial of E. C. Pickering's method of using a reversible objective prism. The star appears to belong physically to the Hyades. It has been further studied at Potsdam by K. Jantzen, who has deduced its orbit as noted above.

The star 88 *d* Tauri is a known spectroscopic binary. At the Princeton Observatory, H. Shapley has found that it is an eclipsing system, and it is likely to prove of special interest in connection with H. N. Russell's views of eclipsing binaries (*Ast. Nach.*, **196**, 383).

The light changes of the star RR Lyræ have been studied by C. C. Kiess (*L.O.B.*, vii. 140). This star is one of the few stars which have the characteristics of "cluster variables" without being situated in a cluster. The velocity determinations made by the same author show that the star is a spectroscopic binary with a period of $0^{d}{\cdot}567$, coinciding with that of the light variation. A relationship between cluster variables and Cepheid variables is indicated.

Effective Temperatures of Stars.—H. Rosenberg (*Ast. Nach.*, **193**, 357) seeks by study of the distribution of intensity in stellar spectra to determine stellar temperatures, and gets results in good agreement with the earlier values of Scheiner and Wilsing.

C. Nordmann (*C.R.*, **156**, 1355), in a similar research, has reached values which also compare well with Rosenberg's values.

A. Pannekoek (*Ast. Nach.*, **195**, 9) calls attention (in connection with Rosenberg's results) to the marked correlation between colour index and spectral class pointed out by him in 1906 as the result of comparing Osthoff's catalogue (*Ast. Nach.*, **153**, 174) with Miss Maury's classification of stellar spectra.

Researches in the Laboratory.—A. S. King describes (*Ap. J.*, **37**, 119, and **38**, 315) noteworthy experiments which seem likely to lead to the recognition of the stationary conditions necessary for the production of enhanced lines. He has succeeded in obtaining enhanced lines in a tube furnace, at the moment when its walls are burnt through by the continued heating of the electric current and a cylindrical arc is formed between the newly formed edges of rift.

H. G. Gale and W. S. Adams (*Ap. J.*, **37**, 391) contribute a short note on the pressure shift of iron lines, in continuation of earlier work. They confirm the observation of St. John and Ware

(*Ap. J.*, **36,** 14), who showed that certain lines are displaced to the violet by pressure.

A. Fowler (*Proc. R.S.*, **89,** 133 and 137) describes his recent work on the spark spectrum of magnesium.

K. Burns (*L.O.B.*, vii. 149, and viii. 27) gives the results of new measures of the lines in the iron arc spectrum: about 120 lines between λ 5434 and λ 8824 were measured at Marseilles with the interferometer of Messieurs Buisson and Fabry, and then over 3000 lines were measured with Professor Kayser's concave grating at Bonn.

F. Goos (*Ap. J.*, **37,** 48) publishes standard wave-lengths in the iron arc spectrum reduced to the international unit, from λ 5328 to λ 6495, in continuation of his previous work (*Ap. J.*, **35,** 221). And the same writer in a later paper (*Ap. J.*, **38,** 141) deals with the difficult question of defining the conditions under which a normal system of wave-lengths may be established from the arc spectrum of iron.

Dr. Kayser (*Ztschr. wiss. Photog.*, **12,** 296) reviews the present position of measurement of wave-lengths in spectra.

Instruments.—J. S. Plaskett (*Ap. J.*, **37,** 373) has made an interesting comparison between the performances of prisms and a grating in stellar work.

F. Schlesinger (*Proc. Am. Phil. Soc.*, vol. **52,** No. 209) reviews the present position of velocity determinations by means of the objective prism and otherwise.

K. Schwarzschild (*Ast. Nach.*, **194,** 241) has given practical trial to the method suggested by E. C. Pickering (*Ap. J.*, **31,** 372) for determining radial velocities with an objective prism. Exposures were made through a thin cell of dilute neodymium chloride, which has been suggested as a suitable absorbent by R. W. Wood (*Ap. J.*, **31,** 376, 460). In deducing the velocity of α Coronæ at 18 different epochs in its orbital period, Schwarzschild found means of testing the accuracy of the adopted wave-length of the neodymium line, and a special determination of the wave-length corroborates the value 4272·79 deduced from the stellar velocity. The lines in the spectrum of α Coronæ are diffuse, and the results of the trial are very instructive.

A. Hnatek (*Ast. Nach.*, **195,** 171) gives a brief description of the spectrograph attached to the 15-inch Coudé equatorial of the Vienna Observatory.

Measurements and Reductions.—P. Kempf (*Ast. Nach.*, **193,** 1) calls attention to a personal error that presents itself in the measurement of the curvature of spectrum lines.

J. Evershed (*Kod. Bull.*, No. 32) describes a new method of measurement of spectra, depending upon the sliding of a positive copy of the plate to be measured over the original plate. The eye estimates coincidence of positive and negative by the resulting uniformity of density in the superposed images. H. F. N.

Astronomy and Wireless Telegraphy.

The reports of many observatories during the past year have recorded the installation of apparatus for the receipt of wireless time-signals sent out from Paris or from Norddeich-Wilhelmshaven. This fact suggests that this may be a convenient occasion for stating the present situation with regard to wireless time-signals. It was in 1905 January that the United States navy department at Washington commenced sending time-signals at noon. It was not till five years later that similar signals were available on this side of the Atlantic. In 1910 May a regular service was started from the Eiffel Tower wireless station and from Norddeich. Naturally, the question of some international scheme to regulate the nature and hours of time-signals was soon raised. On the initiative of Poincaré and others a conference was called together in Paris in 1912 October to discuss the whole question. An international commission, with headquarters at Paris, was created. It was decided to aim at covering ultimately the whole globe with a network of stations so arranged in position that at every point of the globe it should be possible for at least two time-signals to be received in the course of every 24 hours, one by night and one by day. The signals should be sent out according to a detailed scheme at level hours of Greenwich time. So far as the British Isles are concerned, the hours of the Paris signal, 10 a.m. and 12.0 midnight, and of the Norddeich signal, 12.0 noon and 10 p.m., when finally adopted, will be of chief importance. This will probably not take place before 1915 January 1.

The signals are sent at a wave-length of about 2000 m., and conform to a given arrangement of dots and dashes. It may be stated here that this arrangement has not yet been generally approved and adopted. Paris sends the new international signal at 10 a.m., but experiments are being continued to find a set of signals more suitable for use with ship stations at long range. Meanwhile some of the stations are retaining their old signals; the Eiffel Tower at 10.45 a.m. and 11.45 p.m., and Norddeich at noon and midnight. These time-signals are followed by weather-reports modelled on a plan approved by the International Conference, but modified from time to time by the inclusion of reports from fresh meteorological stations.

Of more interest to astronomers is the rhythmic set of signals sent out by the Eiffel Tower about 11.30 p.m. each night. Dots are sent out every 0·98 sec., and, by the method of coincidences, offer a means of very exact comparison between the Eiffel Tower time and the time given by the clock of the receiving station. The time of the first and last signals is sent out later by Paris. Observatories participating in the scheme determine from their own observations the Greenwich mean time of the first and last dot of the series, and inform Paris. Paris can thus correct its own time by comparison with other observatories—a useful correction

during long spells of bad weather. All within reach of the Eiffel Tower signal are thus informed of the time given by the group of participating observatories.

The method of wireless telegraphy suggests itself as being very useful in longitude determination. Already several such investigations have been carried out: the experiments between Paris and Uccle have shown that the probable error of the determination is slightly reduced as compared with previous methods (*Ann. de l'Obs. Royale de Belgique*, xiv. 1). The observations for the determination of the longitude difference between Paris and Arlington—the United States naval station—would give us a value of the velocity of the Hertzian waves, correct to the second significant figure, if we knew the path travelled by the waves. It may instead give us information as to the nature of the path followed. A preliminary account of this work has been published by B. Baillaud (*C.R.* clvi. 758), but the observations are at present being continued with automatic records of the signals. Other applications of wireless time-signals are obvious; they have long been used by navigators. They are found to be extremely useful in the field to geodesists working on the greater surveys; and a portable station might well be useful to eclipse observers.

It may be useful to add here a few references:—

Annales du Bureau des Longitude, tome ix., report of the International Conference; *Annuaire du Bureau des Longitudes*, 1913, 1914, Notice B, interesting historical notes, with description of the Eiffel Tower apparatus and details of the international conference; *Réception des Signaux Radiotélégraphiques transmis par la Tour Eiffel*, Bureau des Longitudes, 1913; *Observatory*, xxxvi. p. 471, report of the last meeting, in 1913 October, of the Conférence Internationale de l'Heure. F. J. M. S.

Latitude Variation.

It is now eleven years since the Council report contained a note on the variation of latitude. During this time a continuous series of observations have been made at the six international stations in the northern hemisphere and a shorter series at two southern stations. A summary of the results and a very short résumé of the problems raised would therefore appear not out of place.

The note in the Report of 1907 February gave an account of the discovery of the Kimura (z) term in the variation, an annual term with amplitude of about $0''.06$ of the same value and phase at all stations on the same latitude.

Later Albrecht (*A.N.*, 178) showed that the value of z is nil on March 9 and September 12, and maximum and minimum on June 10 and December 10, *i.e.* about ten days before the equinoxes and solstices respectively. Kimura, discussing the observed variation from 1890–1908 (*A.N.*, 181), concluded that z was changing

very slowly, possibly in a period of 60–75 years. Up to 1906 observations were made only in the northern hemisphere. From 1906 two southern stations were added. The observations at these showed that z had the same amplitude as in the north, and nearly the same phase.

The great difficulty in elucidating z lies in the fact that there are so many annual terms which might come into play that the separation of them is an extraordinarily complicated question. In the first place, we have to consider whether the term is an annual one at all. If the observations are taken at about the same time every night, any variation with a period of a sidereal day would appear in the final reduction as an annual periodicity. Thus De Sitter (*A.N.*, 166) argued that the "Oppolzer" terms, depending on the attraction of sun and moon, would account for a large part of the observed value of z. Ross, however (*A.N.*, 192), showed that two out of the three "Oppolzer" terms were inoperative, while the third might give a Kimura term, but hardly with any approach to the observed amplitude. In 1905 Kimura (*A.N.*, 169) discussed ten years' observations with the special object of separating a daily term, and could find no evidence for its existence.

If z is a true yearly term, the causes which might be operative to produce it are:—

(1) An actual shift of the earth's centre of gravity along the axis.

(2) An error in the accepted mean parallaxes or mean proper motions of the observation stars.

(3) An error in the accepted aberration constant or nutation theory.

(4) A seasonal change affecting either the instruments or the observers.

(5) A yearly term in the refraction.

We may take these seriatim and very briefly summarise the arguments.

(1) The only obvious cause for such a movement is the alternate accumulation and melting of polar ice. Van de Sande Bakhuysen showed (*A.N.*, 165) that to fit in with observed value of z the path of the centre of gravity must have an amplitude of 3 metres, which if caused by ice would mean that a cap of ice 1 kilometre thick and 244 square degrees in area is melted annually. This is a quite impossible amount.

(2) It was long ago pointed out by Chandler (*A.J.*, 530) that an annual term would be introduced by an error in the accepted mean parallax of the observation stars.

To get the observed value of z would require that the mean parallax of the selected 6 mag. stars should be $0''{\cdot}14$. This is much larger than would generally be considered possible, but as all parallaxes are based upon differential measures, there is no absolute disproof of it. We can only say that it would entirely revolutionise our idea of the stellar universe.

An error of $+0''{\cdot}016$ yearly in the accepted mean proper

motions would give a quite near approach for the value of z. F. Biske (*A.N.*, 175).

(3) The effect of a change in the aberration constant is complicated, but cannot (Ross, *loc. cit.*) be very large.

The effect of neglected nutation terms similarly can, at the most, account for only a small part of the value of z.

(4) Nothing can be said about these except that they may possibly exist.

(5) This remains as the most likely cause for, at all events, the greater part of z.

Such a yearly term in the refraction does not mean the presence of an actual refracting medium round the sun (v. *Observatory*, 1913 August), for this interpretation of the observed quantities would give a medium of quite impossible density, but rather a curving, or tilting of the mean isobaric surfaces in the atmosphere with a seasonal periodicity.

Such a displacement of the isobars is *prima facie* highly probable, and the phase times of the Kimura term, nil at equinoxes, max. and min. at solstices, fit in perfectly with this explanation.

Further observations are necessary, especially at widely different latitudes. The northern stations of the International Geodetic Service are on latitude 39° 8′, while the two southern ones are at 31° 55′; the values of cos ϕ are therefore so nearly the same, that we cannot say what function z is of the latitude. Observations both on the equator and at high latitude are desirable, and also observations of zenith stars visible in daylight.

In addition to the three periodic movements of the earth's axis, the yearly rotation, the 14-monthly rotation, and the Kimura term, there are superimposed irregular disturbances due presumably to meteorological causes such as melting of polar ice, and possibly earthquakes or slow movements of the earth's crust. It was shown by Larmor and Hills (*M.N.*, lxvii. 22) that by a graphical construction these could be readily separated out from the periodic movements and the curve representing the varying torque on the axis of rotation plotted. This when studied in connection with the observed meteorological and seismological factors should go far to elucidate the true causes at work giving rise to the irregular movements of the pole. E. H. H.

LIST OF PUBLIC INSTITUTIONS AND OF PERSONS WHO HAVE CONTRIBUTED TO THE LIBRARY, ETC., SINCE THE LAST ANNIVERSARY.

The Dominion of Canada.
His Majesty's Government in India.
The Lords Commissioners of the Admiralty.
H.M. Secretary of State for the Colonies.
The French Government.
Board of Education.
British Association for the Advancement of Science.
British Astronomical Association.
British Horological Institute.
Institution of Electrical Engineers.
London, University College.
Mathematical Association.
Meteorological Office.
National Physical Laboratory.
Physical Society of London.
Royal Institution.
Royal Observatory, Greenwich.
Royal Photographic Society of Great Britain.
Royal Society of London.
Solar Physics Observatory, South Kensington.
Belfast Natural History and Philosophical Society.
Cambridge Observatory.
Cambridge Philosophical Society.
Cardiff, Astronomical Society of Wales.
Chatham, Royal Engineers' Institute.
Dublin, Royal Irish Academy.
Dublin, Royal Society.
Edinburgh, Royal Observatory.
Edinburgh, Royal Society.
Leeds Astronomical Society.
Manchester Literary and Philosophical Society.
Oxford, Clarendon Press.
Oxford, Radcliffe Observatory.
Oxford, University Observatory.
Stonyhurst College Observatory.
Algiers, Observatoire.
Allegheny Observatory.
Amsterdam, Koninklijke Akademie van Wetenschappen.
Ann Arbor, Detroit Observatory.
Antwerp, Société d'Astronomie.
Arcetri, Reale Osservatorio.
Athens, Observatoire National.
Bamberg, Remeis-Sternwarte.
Barcelona, Sociedad Astronomica.

Basel, Naturforschende Gesellschaft.
Batavia, Koninklijke Vereeniging in Nederländsch-Indie.
Batavia, Royal Magnetical and Meteorological Observatory.
Berlin, Deutsche Physikalische Gesellschaft.
Berlin, Königlich Astronomisches Recheninstitut.
Berlin, Königlich Preussiche Akademie der Wissenschaften.
Berlin, Königliche Sternwarte.
Bern, Universität.
Bologna, Reale Accademia delle Scienze.
Bombay, Government Observatory.
Bordeaux, Observatoire.
Bordeaux, Société des Sciences Physiques et Naturelles.
Boston, American Academy of Arts and Sciences.
Breslau, Königliche Sternwarte.
Brussels, Académie Royale des Sciences de Belgique.
Brussels, Société Belge d'Astronomie.
Budapest, Magyar Tudományos Akadémia.
Canada, Royal Society.
Cape of Good Hope, Royal Observatory.
Cape Town, Royal Society of South Africa.
Cape Town, South African Association for the Advancement of Science.
Catania, Reale Osservatorio.
Catania, Società degli Spettroscopisti Italiani.
Copenhagen, Kongelige Danske Videnskabernes Selskab.
Copenhagen, Observatorium.
Cordoba, Observatorio Nacional Argentino.
Cracow, Académie des Sciences.
Egypt, Survey Department.
Geneva, Société de Physique et d'Histoire Naturelle.
Genoa, Istituto Idrografico.
Göttingen, Königliche Gesellschaft der Wissenschaften.
Göttingen, Königliche Sternwarte.
Granada, Observatorio Astronómico, Geodinamico y Meteorológico.
Halle, Kaislerlich Leopoldinisch-Karolinische Akademie.
Hamburger Sternwarte in Bergedorf.
Harvard College Astronomical Observatory.
Heidelberg, Astrophysikalisches Observatorium.
Helsingfors, Finska Vetenskaps Societet.
Helwân, Khedivial Observatory.
Hobart, Royal Society of Tasmania.
India, Astronomical Society.
India, Survey Department.
Japan, Astronomical Society.
Johannesburg, Union Observatory.
Kasan, Observatoire Astronomique de l'Université Impériale.
Kiel, Sternwarte.
Kodaikánal Observatory.

Kyoto, Imperial University.
Leiden, Sterrenwacht.
Leipzig, Astronomische Gesellschaft.
Leipzig, Fürstlich Jablonowski'sche Gesellschaft.
Leipzig, Königlich Sächsische Gesellschaft der Wissenschaften.
Lick Observatory.
Lille, Observatoire.
Lisbon, Academia das Sciencias.
Lowell Observatory.
Lund, Astronomiska Observatorium.
Madrid, Observatorio Astronomico.
Madrid, Real Academia de Ciencias.
Meudon, Observatoire Physique de Paris.
Milan, Reale Osservatorio di Brera.
Missouri University, Laws Observatory.
Montpellier, Académie des Sciences et Lettres.
Moscow, Gesellschaft von Freunden der Astronomie.
Moscow, Observatoire Astronomique.
Mount Wilson, Solar Observatory.
Münich, Königlich-bayerische Akademie der Wissenschaften.
Naples, Reale Osservatorio di Capodimonte.
Naples, Reale Accademia delle Scienze.
Neuchatel, Observatoire Cantonal.
Oporto, Academia Polytechnica.
Ottawa, Dominion Observatory.
Palermo, Reale Osservatorio.
Páris, Académie des Sciences.
Paris, Bureau des Longitudes.
Paris, Observatoire.
Paris, Société Astronomique de France.
Paris, Société Mathématique de France.
Paris, Société Philomathique.
Perth Observatory, Western Australia.
Perth, Western Australian Astronomical Society.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Philadelphia, University of Pennsylvania.
Potsdam, Astrophysikalisches Observatorium.
Potsdam, Central Bureau der Internationalen Erdmessung.
Potsdam, Königlich-preussische Geodätisches Institut.
Prague, K. K. Sternwarte.
Pulkovo, Observatoire Central Nicolas.
Rio de Janeiro, Observatorio.
Rome, Reale Accademia dei Lincei.
Rome, Società Italiana delle Scienze.
Rome, Specola Astronomica Vaticana.
San Fernando, Instituto y Observatorio de Marina.
San Francisco, Astronomical Society of the Pacific.

Santiago de Chile, Observatorio Astronomico.
St. Petersburg, Académie Impériale des Sciences.
Stockholm, Kongliga Svenska Vetenskaps-Akademie.
Stockholm, Observatorium.
Sydney, Royal Society of New South Wales.
Tacubaya, Observatorio Astronómico Nacional.
Talence (Gironde), Observatoire.
Tiflis, Physikalisches Observatorium.
Toronto, Canadian Institute.
Toronto, Royal Astronomical Society of Canada.
Tortosa, Observatorio del Ebro.
Toulouse, Académie des Sciences.
Toulouse, Observatoire Astronomique.
Turin, Reale Accademia delle Scienze.
Turin, Reale Osservatorio Astronómico.
Turin, Società Astronómica Italiana.
Turin, Società Urania.
Uccle, Observatoire Royale de Belgique.
Upsala, Kongliga Vetenskaps-Societet.
Vienna, Kaiserliche Akademie der Wissenschaften.
Vienna, Osterreichische Kommission der Internationalen Erdmessung.
Vienna, Von Kuffner'sche Sternwarte.
Warsaw Observatory.
Washington, National Academy of Sciences.
Washington, Carnegie Institution.
Washington, Navy Department.
Washington, Smithsonian Institution.
Washington, United States Coast and Geodetic Survey.
Washington, United States Naval Observatory.
Yerkes Observatory.
Zi-Ka-Wei, Observatoire Astronomique de Zô-Sè.
Zürich, Naturforschende Gesellschaft.
Zürich, Sternwarte des Eidg. Polytechnikums.
Editors of the "American Journal of Mathematics."
Editors of the "American Journal of Science."
Editor of the "Astronomical Journal."
Editor of the "Astronomische Nachrichten."
Editor of the "Astronomischer Jahresbericht."
Editors of the "Astrophysical Journal."
Editor of the "Athenæum."
Editor of Brown's Nautical Almanac.
Editors of the "Bulletin des Sciences Mathématiques."
Editor of the "English Mechanic."
Editor of "Himmel und Erde."
Editor of "Knowledge."
Editor of "Nature."
Editors of "The Observatory."
Editors of "Popular Astronomy."
Editor of "Sirius."

Sr. N. Rojas Acosta.
M. Henri Arnauld.
Prof. A. Auwers.
Prof. Van de Sande Bakhuyzen.
Prof. E. E. Barnard.
Mr. C. L. Brook.
Dr. Kr. Birkeland.
Prof. W. W. Campbell.
M. S. Chevalier.
R. G. Corney, Esq.
M. Henri Deslandres.
C. R. D'Esterre, Esq.
Dr. J. L. E. Dreyer.
M. Camille Flammarion.
Dr. H. Fritsche.
Sr. J. Garavito.
Prof. R. Gautier.
Sir David Gill.
Lady Gill.
Prof. J. G. Hagen.
Henry Hart, Esq.
Prof. E. Hartwig.
Ellison Hawks, Esq.
T. E. Heath, Esq.
Rev. A. C. Henderson.
A. R. Hinks, Esq.
R. T. A. Innes, Esq.
M. R. Jarry Desloges.
Lady Huggins.
M. Ernest Lebon.
Dr. J. R. Leeson.
Mme. Ida Lehmann.
Fredk. C. Leonard, Esq.
Sr. E. Lopez.
Col. E. E. Markwick.
E. W. Maunder, Esq.
Dr. O. T. Olsen.
Dr. A. Pannekoek.
Dr. H. N. Russell.
Harlow Shapley, Esq.
Prof. W. de Sitter.
M. Carl Störmer.
M. Paul Stroobant.
Prof. H. H. Turner.
W. L. Webb, Esq
Prof. Max Wolf.
Prof. A. Wolfer.

ADDRESS

Delivered by the President, Major E. H. Hills, C.M.G., D.Sc., F.R.S., on presenting the Gold Medal of the Society to Dr. Max Wolf.

The Council has resolved that the Gold Medal of the Society be awarded to Dr. Max Wolf for his work in Celestial Photography and Spectroscopy, and it now devolves upon me to lay the reasons for this decision before you.

If we look at the list of the Gold Medal awards we shall see that they may be divided into two main classes: we have, firstly, medals given for definite and completed pieces of work, and, secondly, medals given to followers of our science who have devoted their whole life to its advancement and whose activities have often covered a wide range of subjects. To this latter class our Medallist of to-day belongs. We offer him the highest reward in our power, not so much for this piece of work or that piece, but in recognition of a life spent in astronomical research—research of the most fruitful character along lines which I may perhaps be allowed to call the great highroads of astronomical advance during the past thirty years: celestial photography and spectroscopy.

In offering our medal to Dr. Wolf we are giving it to one who not only has a fine record of accomplishment behind him, but also, we trust, a long period of activity yet to come, so that the award may fairly be said to have a double character: both an appreciation of the past and an encouragement for the future. My task in presenting to you a succinct and, as far as time will permit, complete summary of the astronomical work of our Medallist will, therefore, necessarily take the form of a scientific biography—fortunately, however, an unfinished biography of which we hope to read many future chapters in the publications of the Heidelberg Observatory and elsewhere.

Dr. Max Wolf was born in 1863, and devoted himself to astronomy at a comparatively early age. In 1884 he discovered a periodic comet with an equatorial of his own construction. In the year 1879 he and his father, Dr. Franz Wolf, a practising physician in Heidelberg, built an observatory in the garden of their house. This was equipped in the first instance with a 6-inch refractor by Reinfelder and Hertel, and afterwards a double photographic camera, furnished with 6-inch Voigtländer doublet portrait lenses, was placed on the same mounting. Many other lenses were used, all with the consistent object of experimenting in the direction of the photography of large fields, amounting in the case of one camera to a maximum of $24^\circ \times 19^\circ$ and, in the case of the Voigtländer lenses, to a field of $12^\circ \times 8^\circ$.

I perhaps need hardly pause to point out that in the early days of astronomical photography astronomers were very shy about the employment of lenses covering large fields, and that at this time Wolf in Europe and Pickering in America were the great protagonists in the use of this class of instrument. How well their use has served the cause of astronomical discovery is known to you all, and it was but a short time after he had begun to make serious observations of this character that our Medallist showed that for one particular sort of discovery, the discovery of minor planets, the camera of large field was without a rival. This result was not reached without much preliminary unsuccessful experimentation. The conditions of the problem were not at first completely realised, and the earlier instruments failed because either their aperture was too small or their ratio of focal length to aperture too great.

In photographing a planet, when the camera is guided on a star, we get a trail the intensity of which will vary approximately as the area of the lens divided by the focal length. In other words, the ratio aperture to focal length remaining constant, the intensity will vary directly as the diameter of the lens. For securing trails of such faint objects as the minor planets we, therefore, require a large aperture combined with a small ratio of focal length to aperture, and, further, if it is a question of the discovery of new planets, good definition over a large field is imperative. Our Medallist began his work upon these lines in 1890, but it was not until 1891 December 22 that he attained his first success and discovered the new minor planet (323) Brucia. This discovery was made on a plate taken with a Kranz lens of 5 inches aperture and a ratio D^2/F of 2·2.

From this point forward his progress was rapid. On plates taken with this lens between 1891 November 28 and 1892 March 24 no fewer than 18 new or apparently new planets were found.

In 1892 a more efficient instrument, the 6-inch Voigtländer portrait lens, was mounted, supplemented in 1895 by a second lens of identical pattern.

By the simultaneous use of two lenses much time was saved. Two plates were always necessary for the sure identification of a new object. To obtain planets of 12–13 magnitude, at least half an hour, and, better, about two hours' exposure was required. By the use of the double camera these exposures could be arranged so that they partly overlapped in time—*e.g.* the first camera could be exposed for one hour, then both for a second hour, and then number one closed and number two left open for the third hour. This reduced the necessary time of exposure from four to three hours, and still gave two two-hour exposures following each other. The enormous advantage of this photographic method of search above the old laborious visual method was soon apparent—an advantage which will not astonish us when we consider that for planets above 12·6 mag. a field of no less than 70 square degrees could be used. For feebler planets the usable field had to be pro-

portionately reduced, but remained always vastly greater than in any visual instrument.

The success met with was immediate. Not only were many new planets discovered but large numbers of old ones were rediscovered and reobserved. In fact it is hardly too much to say that even had no new planets been found, the method would have amply justified itself by its value for the reobservation of known objects of this class.

During the first year's use of this instrument (1892) 18 new planets were found, and 38 known ones were rediscovered. In the following year the corresponding figures were 9 and 27.

Our Medallist's industry and success in this work has continued unimpaired. Up to the present time no less than 316 new minor planets have been found by himself and his assistants. When I was writing this address I saw the list of the minor planet discoveries in 1913. Out of a total of 88, no fewer than 32 came from the Heidelberg Observatory.

The heavy labour of examining the plates for these faint objects caused Dr. Wolf much anxious thought, and he was one of the first to see that the ideal form of comparator would be an instrument combining into a single stereoscopic picture the images on two plates placed side by side, whereby any difference between the two—such as an object present on one and absent from the other, or an object which has changed its position or its intensity between the two exposures—would be at once apparent. This problem occupied his attention for many years without his arriving at any success. Eventually it was solved by Dr. Pulfrich at Jena, who was engaged on the cognate problem of a stereoscopic distance-measurer or range-finder. Dr. Wolf at once saw that the optical arrangement of his instrument was capable of being put to the exact use he had so long desired, and he lost no time in getting an instrument made and testing it. The identification by it of minor planet trails, where the exposures are made at different times, and where therefore there is a change in position, was a comparatively simple matter. A far more rigorous test, and one that was immediately applied, was to use the instrument for the discovery of variable stars. To this end plates of the region in the vicinity of the Orion nebula, containing one well-known variable, S Orionis, were examined, with the result that 10 new variables were discovered, all previously unknown to the observer.

Dr. Wolf might well claim (1901 October) that the introduction of the stereo-comparator marked a new era in the discovery of variable stars, similar to that before accomplished by the use of the doublet objective for small planet discoveries.

It was also obvious that for the finding of stars of large parallaxes or proper motions this instrument would prove of capital service; to this and to its application by Dr. Wolf to the discovery of small nebulæ we must revert later.

This minor planet discovery was by no means the only purpose to which our Medallist put his astrophotographic instruments.

From an early date he had directed his attention to the photography of faint and extended nebulæ and to the elucidation of the problem of their connection with the enclosed and surrounding stars.

Three regions of the sky attracted his particular attention, Orion, Cygnus, and Auriga. In this research he showed his usual skill and industry. In Cygnus he discovered the faint "America" nebula (1890 December 12). In the Orion region he, in common with Professor Barnard, showed that in three of Herschel's suspected nebulous regions, Nos. 22, 23, and 24, distinct nebulosity was to be found. That the successful photography of these faint luminosities was not an easy matter is evident from the fact that Dr. Isaac Roberts, photographing the same region systematically, both with his 20-inch mirror and with a 5-inch portrait lens, could find no trace of nebulous matter.

A similar tribute to his skill may be derived from the fact that he has repeatedly photographed the faint northerly continuation of the Orion nebula of which Pickering wrote (January 1890): "It is very doubtful if any of the fainter nebulous extensions can be photographed at any observatory in or near a town."

A like success was reached by him in the case of another of the now well-known nebulous clouds, that lying outside the Pleiades. Our Medallist's first observations of this were published in 1891, and he often photographed it afterwards. Professor Barnard's beautiful photographs of this field, first published in 1894, are doubtless known to all of you. As another example may be cited the discovery of the great nebulosity near ψ Eridani, between that star and λ Orionis. This object is very far south for successful observation at Heidelberg, so that to get many photographs of it is no small achievement.

The large quantity of material thus secured by him was not long in yielding results of the highest interest.

Sir W. Herschel, in his "Account of some Observations tending to investigate the Construction of the Heavens" (*Phil. Trans.*, lxxiv.; *Collected Papers*, vol. i. p. 164), wrote: "In my late observations on nebulæ I soon found that I generally detected them in certain directions rather than in others; that the spaces preceding them were generally quite deprived of stars, so as often to afford many fields without a single star in it; that the nebulæ generally appeared some time after among stars of a certain considerable size, and but seldom among very small stars. . . . But how far these circumstances of vacant places preceding and following the nebulous strata, and their being, as it were, contained in a bed of stars sparingly scattered between them, may hold good in more distant portions of the heavens which I have not yet been able to visit in any regular manner, I ought by no means to hazard a conjecture. The subject is new, and we must attend to observations and be guided by them before we form general opinions."

It was reserved to our Medallist, more than a century later, to complete and verify this speculation. He was able to show from

numerous photographs taken by him and at his observatory that all the extended nebulæ of our Milky Way system are situated in the interior of regions containing only a very small number of faint stars, and furthermore that the nebulæ are always at one side of these lacunæ or star caves, the nebulæ appearing to come into existence where the stars suddenly became less and almost no small stars are to be found. The nebula is in general surrounded by a quite narrow ring of "star emptiness," but the great cave is always on one side of it, often forming a large starless channel or hole. So accurately does the outline of the star cave follow that of the nebula, on the side where it is close to it, and so rapid is the falling-off in the number of stars, that it would be possible to make a quite precise drawing of the outline of the nebula without seeing it at all. On the average, faint stars are about ten times more numerous inside the nebula and far outside it than they are in the surrounding star cave. This remarkable conclusion, which must surely be taken into consideration in any future theories on the evolution of our universe, was verified by Dr. Wolf in numberless cases, and I am not aware that there is any known exception to it. The fields examined by him up to 1903 include:—Orion with three nebulous masses: the great Orion nebula, the ζ Orionis nebula, and N.G.C. 2064–2068; the two nebulæ in Sagittarius (Messier 8 and Messier 20, the Trifid); the extended nebulæ by γ Scuti, ρ, δ, and θ Ophiuchi, ν Scorpii, η Carinæ, S Monocerotis, ξ Persei, β Cassiopeiæ, northward from Antares, the "America" nebula in Cygnus, and less marked in the nebulæ surrounding the Pleiades Afterwards he continued these observations and discovered several more which exhibit this cave formation in a striking form: among these are π_2 Cygni, τ Cephei, and a new nebula in Cepheus discovered by him in 1908.

The case of the nebulæ of which the great nebula in Andromeda is the type, including the spiral nebulæ such as Messier 33, N.G.C. 3249, and innumerable others, is entirely different. In all these star caves are completely absent, in fact the presence or otherwise of these empty spaces appears to form a critical distinction between these two great classes of nebulæ.

The exposure of these nebular plates often exceeded 10 hours, and reached a maximum of 16½ hours, spread over 5 nights.

Having thus far spoken of our Medallist's success in dealing with faint extended nebulous clouds, I now turn to another branch of his work, the photographic discovery of small nebulæ—a work to which he has devoted unremitting energy for many years, and which he would, I think, be inclined to consider the most important task he has been engaged upon.

Before doing so, I shall, however, interpose a short résumé of the history of his observatory, enabling us to follow the progress of the work more readily. From 1891 to 1897 the observations were all made at the private observatory at Heidelberg, first with the Kranz and a number of other experimental lenses, and latterly with the two Voigtländer lenses already alluded to.

In 1897 this observatory was dismantled, and the instruments transferred to the Baden State Astrophysical Observatory on the Königstuhl, Heidelberg. This transfer occupied exactly one year, the last photograph in the old observatory being taken on 1897 June 29, and the first one at the new observatory on 1898 June 28. Dr. Wolf had been appointed Director of the new Astrophysical Observatory in 1893, and laid out a programme along the lines of his earlier work. This programme he was enabled to amplify and extend through the generosity of Miss Katherine Wolfe Bruce, who made the observatory a most welcome and valuable gift in the form of a new double telescope, of 16 inches aperture. The lenses were made by Brashear on the Petzval formula, with a ratio of aperture to focal length the same as the Voigtländer lenses—1 to 5, and a field of $8^\circ \times 6^\circ{\cdot}5$. This instrument took its first photograph on 1900 August 29, and has since that date been in continuous and fruitful use.

In the course of his early work on the photography of faint nebulæ and in the search for small planets Dr. Wolf was surprised to find how unexpectedly great, in all parts of the heavens, the number of small and planetary nebulæ was. Especially so was this the case with the plates taken with the Voigtländer lenses, which gave in many parts of the sky fields quite filled with nebulous spots (Nebelflecken). Thus, as an extreme example, a plate taken on 1892 March 24 with 96 minutes' exposure showed, in a circle of 1° radius with η Virginis as the centre, 130 of these little nebulæ. Similar numbers, but only seldom so immensely great, were found in other parts of the sky, and it was thus obvious that the doublet lens of large aperture and short focal length would reveal the sky filled with small nebulæ to a number enormously greater than had been contemplated as possible. At a later period, when he had completed five large regions, Dr. Wolf estimated that the total number of unknown nebulæ in the whole heavens was about 260,000. At the same time it was clear that the photographic method was paramount both for the detection and position measurement of such objects. He accordingly decided to give special attention to these little nebulous spots, and began at once taking plates of those regions where it was known that small nebulæ were plentiful. Thus in the course of the next year the regions of Virgo, Leo and Coma Berenices were covered, for the most part three times over.

It was now necessary to devise methods for the measurement of the positions on the plate. In the case of the minor planets this had at first been done by triangulation from three known stars, measuring the distance from planet trail to star with a Bamberg screw micrometer; afterwards a new method was devised in which only two reference stars were required. This process, quite satisfactory when only one or two unknown objects on a plate had to be measured, was far too slow and laborious when the numbers mounted to hundreds, and it was at once obvious that some new method must be sought for.

A solution was found in the Kapteyn parallactic measuring apparatus. This machine is based upon the simple principle that if a photographic plate is fixed at a distance from a short-focus telescope equal to the focal length of the lens with which it was taken, the relative positions of the images on the plate, as viewed through the telescope, will be exactly the same as if the objects themselves were observed in the sky. If, therefore, the telescope is provided with two graduated circles at right angles to each other, it can be so adjusted that the right ascensions and declinations of all the objects on the plate can be read directly off these circles. No calculation for the conversion of rectangular co-ordinates into angular measurements is necessary. The instrument is probably not capable of the very highest degree of precision: it cannot compete in this respect with the best forms of screw or réseau micrometer; but it is very rapid and was perfectly adapted to the purpose required. An elaborate investigation of its errors was made at the Heidelberg Observatory by Dr. Schwassmann, who improved the method of use so that a quite satisfactory accuracy was attained. When, however, the Bruce telescope came into use and the distance between the measuring apparatus and the plate had to be increased to 80 inches, the problem of the relative stability of plate and measurer became more difficult. Dr. Wolf was then faced with the alternatives of either abandoning the highest possible precision or of allowing the measuring to fall hopelessly into arrear. He quite rightly decided for the first alternative, deliberately reduced his standard of accuracy, simplified the process of measurement, and, as a result, has been able to discover and record new nebulæ at an unexampled rate.

When I speak of reducing the order of accuracy and extol our Medallist's sound judgment for so doing, it must not for one moment be supposed that his work is of a rough or approximate character. On the contrary, it is certain that the position of these small nebulæ are recorded by him with a precision substantially greater than could have been obtained by any visual method. It must be remembered that the problem of determining the position of a small nebula is essentially different from the same problem in the case of a minor planet. With planets the main advantage of the photographic method lies in the facility with which new ones are discovered or old ones rediscovered. Once found, and their approximate positions known, their precise co-ordinates can be obtained more rapidly and more accurately with visual instruments. The fact that the measurement on the plate must be of a trail, of which the two ends are not strictly comparable—the altitude, and consequently the apparent brightness, differing appreciably at the beginning and end of the exposure—introduces an uncertainty into the photographic determination of place which is absent from visual observations. With nebulæ the conditions are reversed. The irregularity of shape and, even if quite symmetrical, the size of the object make it very difficult to estimate the exact moment when the centre passes the cross wires

in a visually observed transit, whereas in measuring a stationary plate it is much more easy to make an accurate bisection.

Dr. Wolf's computations of nebular positions are carried to one-tenth of a second of arc and one-hundredth of a second of time; the actual limits of uncertainty are probably about, or perhaps slightly over, ten times these figures. These are, therefore, the limits adopted in the published lists—one second of arc and one-tenth of a second of time.

As an example of the rapidity of the work, a set of plates with 1528 nebulæ, on which 72 reference and orientation stars were used, took 41 sittings of 2 hours each for complete measurement. If the precise and more laborious procedure devised by Dr. Schwassmann had been used, the reduction of this single field would have occupied not less than a year.

The sizes are estimated on a scale similar to that used by Sir J. Herschel, running from "most extremely small" of under 4″ diameter up to "excessively large" of 20′ and more, the brightness on a scale similar to Herschel's of twelve grades. It is, as Dr. Wolf points out, difficult to compare two scales—one based on visual and one on photographic estimations, and it is possible that his brightness magnitudes are slightly greater that Herschel's; the systematic difference is, however, small.

The forms are classified under three main heads:—

(I.) Regular, with five subdivisions: (1) round, with a central condensation; (2) round, condensed, with a twisted or spiral tail coming out of the condensation; (3) Andromeda-shaped and oval, with central condensation; (4) planetary and round, small and diffuse, without core; (5) long and oval, without core.

(II.) Irregular, with two subdivisions; (1) irregular, with a decided core; (2) all other irregular shapes.

(III.) Structureless, including all diffuse nebulæ with no recognisable structure.

For further description Herschel's nomenclature is used with a few additional notes as found necessary.

The classification of nebulæ is a subject to which Dr. Wolf has devoted much attention. As he points out, difficulty arises from the fact that there are hardly two nebulæ in the heavens of exactly the same shape. Obviously the ideal would be one based upon the spectrum, but the number of which the spectrum is known is so small a proportion of the total that this seems to be out of reach for many years. In 1908 he proposed a system of twenty-three standard types, now partially adopted for his catalogues. In the rapid detection of nebular images and their separation from accidental spots or faint stars on the plates, the stereo-comparator has proved of inestimable service. The procedure adopted is to compare two similar plates, utilising the principle that objects of different colours will appear in the stereoscopic image to lie on different planes: thus a gaseous nebula with a bright line spectrum will appear to stand out from a field of stars with absorption spectra. This gives a critical distinction between a nebula and

a cluster which might seem to be almost too elusive for general, practical use. It has, however, proved invaluable in the skilful hands of our Medallist.

As an example of one of his earlier nebula lists we may cite that of the region round the pole of the Milky Way. This part of the sky had a special interest, as it had been known since Herschel's time that small nebulæ had a definite relation to the Galaxy and that their numbers would increase as one approached the pole. Thus Sir J. Herschel, after speaking of the region in Virgo which contains the richest concentration of nebulæ in the northern heavens, writes (*Results of Observations at the Cape of Good Hope*, pp. 136, 137): "It must not be left out of consideration and has been distinctly remarked by Sir Wm. Herschel as an element of whatever speculation a closer attention to this subject and a more perfect classification of nebulous objects may lead us to indulge in, that the most condensed portion, and what may be regarded as the principal nucleus of the region of Virgo, is situated almost precisely in one pole of the Milky Way. . . . Indeed, there are few features more remarkable in the constitution of the Milky Way itself than the comparative rarity of nebulæ of the first, second, and third classes" —that is, all nebulæ with the exception of "planetary" and "very large." In the Southern Hemisphere the concentration about the pole, though unmistakeable, is not so sharply defined.

In Dr. Wolf's photographs a rich mass of nebulæ was found about $1\frac{1}{2}^\circ$ from the accepted position of the north galactic pole: in the densest part there were more than 70 in $\frac{1}{16}$th of a square degree, and the question arises as to whether the centre of this cloud of nebulæ defines the pole more precisely than previous estimations.

The total number photographed in this field (about $7^\circ \times 5^\circ$) was 1528, of which 81 were already known and catalogued in the N.G.C. (in 7 cases the identification was not quite certain), while 3 nebulæ given in the N.G.C. could not be found, and it could be stated with certainty that there exist no nebulæ in these places.

Altogether Dr. Wolf has now published the result of fourteen fields—all, with a single exception, taken with the twin 16-inch lenses of the Bruce telescope. The exception is a field in Virgo taken with the Voigtländer 6-inch, measured and reduced by Dr. Schwassmann.

In these fourteen regions 4992 new nebulæ have been discovered, and 431 previously known ones photographed. The average proportion of new to old is therefore about $11\frac{1}{2}$ to 1, but in some places this ratio is far exceeded; the region of 35 Comæ, for example, contained 201 new and only 3 known nebulæ.

I have spoken somewhat at length, but I trust not at undue length, of this work of photographing the small nebulæ, because, in the first place, it is in many senses the most important and striking that our Medallist has undertaken, and, in the second, because it exhibits in a forcible way his peculiar sanity of judgment shown in his refusal ever to allow his methods to run away with him and

his sound solution of the ever-present problem of deciding at what precise point to strike the balance between the ideally possible and practically expedient.

The astronomer is, even more than others who are concerned in precise measurement, often led to set up for himself a standard of accuracy, not perhaps absolutely unattainable, but involving so much labour that its attainment carries with it an undue sacrifice of quantity to quality. I need not here point the moral: instances will be within the knowledge of all of you where great pieces of astronomical work, fruitful of promise in their inception, have become sterilised and barren owing to their authors having been led away by this ignis fatuus—the desire for an impossible refinement. This error Dr. Wolf has avoided, with what results we have seen. That he can, where necessary and expedient, do work of the very highest order of precision may be exhibited by a short reference to two pieces of work carried out by him or under his direction. The first of these was the precise determination of the positions of 178 small nebulæ, only well-known ones being included, and those selected having either a defined core or at least of a sharp, round shape. 179 plates were used, all taken with the Bruce telescope between 1901 and 1910; as evidence of Dr. Wolf's industry we may mention that 60 of these plates were taken by himself: the others were done by his assistants Drs. Kopff and Hellfrich. All measurements were made by identical methods, the "Turner" method with three reference stars, and every possible precaution was taken to get the highest attainable order of accuracy. The reductions were made by Dr. Lorenz, and the result is a catalogue that must be of great value for future discussions of the proper motions and can be compared for this purpose with the Bonn and Strasburg Catalogues. Another piece of work of importance and interest was the application of the stereo-comparator to the determination of stellar proper motions. The principle on which this is based is obvious: the relative shift of any one star gives it the appearance of standing out above or below the general plane of the field as viewed in the microscopes. The fact that the comparison is made not with a single star but with a whole group of stars in the field tends to eliminate the colour equation and thus removes one of the difficulties inherent in visual observations. Whether ultimately this will lead to a greater precision is an open question: in general we may say that we are more likely to attain accuracy by a recognition and correction of individual sources of error than by their partial elimination by a process of averaging. In any case, the method is invaluable for the rapid discovery of stars with large proper motions. Dr. Wolf in his nebular plates has now for many years been accumulating material for this research. So far he has only been able to use the earlier plates taken with the Voigtländer lens; but even this instrument, short as the focal length is for observations of this character, has given him results of great promise.

He has thus discovered many new stars with measurable proper

motions, the first one being a star which had moved 19″ in fourteen years, found in 1905, and we shall look forward with interest to the extension of the research to the beautiful plates taken with the Bruce lenses. It may be added that this method is now in successful use both at Potsdam and at Pulkovo.

In order to render these Bruce photographs more readily available for astronomers, especially for the finding and observation of small planets, Dr. Palisa of Vienna has undertaken their publication. The sheets are 28 × 22 cms. in size, cover 50 square degrees, and show stars down to the fourteenth magnitude. So far 160 of these sheets have been issued.

It might perhaps be thought that I have already said enough to justify the Council in their selection of Dr. Wolf for the honour of the Gold Medal. I have, however, still to speak of his spectroscopic researches—a line of work which he has only been able to follow in recent years, but in which he has already left his mark.

The special direction to which he has turned his attention is the securing of the spectra of very faint objects. He uses for this purpose a spectroscope with a 72-cm. mirror and prisms of "U.V." glass, very transparent in the ultra-violet, making prolonged exposures. Thus for the Ring nebula he took a plate with 20 hours' exposure, spread over 5 nights; for Andromeda 25 hours' exposure, spread over 20 nights; and for the spiral nebula Messier 64, 39½ hours in 14 nights. Later even these have been exceeded, and an exposure has been made of more than 70 hours, extending over two months. Other spectra taken include Comets Halley and Brooks; six Wolf-Rayet stars; two planetary nebulæ, N.G.C. 6543 and 6572; and the "America" nebula; with exposures of 12 hours and under.

Most of his spectra reveal points of novelty and interest. I shall not now attempt to deal with all of them. I take only two examples—the Andromeda Nebula and the Wolf-Rayet stars.

The spectrum of the Great Nebula in Andromeda was photographed by Scheiner in 1898 and 1899 with 3½ and 7½ hours' exposures. From his photographs he deduced that the spectrum was mainly a continuous one, with an intensity curve identical with that of the Sun and some absorption lines: the H_1 line and the G group could be recognised with certainty.

Long previous to that date, though the results were not published till afterwards, the spectrum had been photographed by Sir William and Lady Huggins, who also made an extensive series of visual observations. In a photograph taken in 1888 faint indications of dark lines at the positions of G, H, and K could be detected. In their visual observations they saw dark bands and also bright lines. Especially on one occasion, 1897 November 13, they record that the nebula gave a "continuous spectrum with a great many bright lines in it."

In 1908 August and September, Fath, using the Crossley reflector at the Lick Observatory, secured two plates with 8¾ and 18½ hours' exposures. He found continuous spectrum from F to λ 374 with

a maximum at λ 464. He counted 14 measurable absorption lines which coincided with strong groups of solar lines, but no bright lines

The theory that the whole nebula, or at least its central part, for the outer extensions are too faint for their spectrum to be impressed on the plate in any exposure of practicable length, is an unresolved cluster of solar type stars is one that appeared to fit the spectroscopic results, but raises great difficulties in other directions. Firstly, the distance would have to be enormous, quite outside any measurable parallax, while the only observation of the parallax, that made by Bohlin, has given a value of 0″·17—very much too large for the star-cluster theory. Secondly, there is no obvious reason why the stars in a cluster should be mainly of one spectral type. This objection is, however, not insuperable, for photographs of the spectra of three known star clusters, made at Lick, gave in the case of the Hercules cluster evidence that the stars were of different spectral types and in two other clusters, N.G.C. 7078 and 7089, F type spectra only.

The idea that this great nebula may be a cloud of stars, mainly of the same class as our Sun, situated at an almost inconceivable distance, is one that appeals powerfully to the imagination, and it is not surprising that Dr. Wolf turned his attention to it very soon after he had got a spectroscopic equipment of suitable power. He took two photographs—one with $8^h\ 53^m$ exposure from 1910 October 24 to November 30, and the other with $25^h\ 7^m$ exposure from 1911 February 3 to 22.

From these he obtained 45 absorption lines, coinciding in the main with groups of solar lines, and a point of maximum intensity at λ 453, identical with that obtained with the same instrument and plates for the Moon and Capella.

He is of opinion—though I think I am right in saying that he would like this opinion to be accepted with the reserve that it is not easy to express a final judgment until star spectra of different types have been photographed with the same instrument—that neither the presence nor the absence of bright lines is yet established with certainty, and that while on the whole the spectrum is of II*a* type, it is not exactly a solar one, but seems in some points to resemble that of Aldebaran and in others more those of Arcturus or Capella. Whatever may be the ultimate outcome on this point, our Medallist's photographs of the spectrum mark a great advance and must prove of prime value in any future discussions.

The problem of the Wolf-Rayet stars is one of extraordinary interest and importance. Their close affinity with nebulæ and with novæ, the idea that they are the earliest products of the evolution from nebula to star, and the relations of the wave-lengths of their spectral lines in connection with the daring speculations of our Fellow Professor Nicholson, combine to place them among the most fascinating objects to which the spectroscopist can direct his studies. Their extreme faintness renders this study one of exceptional difficulty.

Dr. Wolf has prosecuted this research with his usual energy

and success. He has now photographed the spectra of six of these stars, adding a large number of lines to those previously known. Thus, for the two stars $+37^{\circ}$ 3821 and $+35^{\circ}$ 4001 he obtained respectively 46 and 39 lines. He got conclusive evidence of the presence of all the hydrogen series; 7 lines of the principal and 6 of the "Pickering" series, and the line at 4634. He also got a strong emission line or band in the ultra-violet at λ 348. This may be identical with a nebula line found by Palmer at λ 345, but it is significant that Professor Nicholson's theory demands a line at about λ 346. Another result is a very strong absorption line at λ 386 not seen by Pickering or Campbell.

These stars are remarkable in that, while there is a general resemblance between the spectra of different individuals, no two are exactly the same. Each star of the class has an individuality of its own and differs in minor, but quite distinctive, particulars from other members of the family. Our Medallist's beautiful series of photographs must when fully studied—and he would be the first to admit that they have yet only been subjected to a preliminary examination,—throw much light on the puzzling problems raised by these inconspicuous bodies.

I have now, I think, given you the most ample reasons why we should desire to place Dr. Wolf upon our roll of honour by presenting him with our Gold Medal. Of him it may be truly said that he has touched nothing he has not improved. In whatever direction we look at his work we see the same evidences of industry, skill, and judgment. His researches are notable not only for their uniform success, but for the fact that they are all of the highest importance in the sense that they deal with phenomena likely to throw light into the darkest corners of physical and cosmical theory. Difficulty appears to have a peculiar attraction for him. Whether we see him photographing faint stars or fainter nebulous clouds, discovering new planets by the score, or new nebulæ by the thousand, our admiration is alike compelled. Even if his work stopped to-morrow—and we have every reason to hope that it is really little more than just beginning, and that his scientific life has many fruitful years before it,—he would leave a great name in our science.

The President then, handing the medal to Dr. Max Wolf, addressed him in the following terms:—

Dr. Max Wolf,—It is to me a source of the most sincere gratification that I have the pleasure of presenting this Medal to you in person. I beg that you will accept it both as a token of our appreciation of your long-continued and valuable observations and as an expression of our esteem for your single-hearted labours towards the advancement of our science. I trust that you have yet many years of health and strength before you. I can promise you that whenever you are able to visit us in London and to describe the results of new and further researches, you are assured of a warm welcome at the rooms of the Royal Astronomical Society.

The Meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:—

President.

Major E. H. Hills, C.M.G., D.Sc., F.R.S.

Vice-Presidents.

F. W. Dyson, Esq., M.A., LL.D., F.R.S., Astronomer Royal.
J. W. L. Glaisher, Esq., Sc.D., F.R.S.
H. F. Newall, Esq., M.A., D.Sc., F.R.S., Professor of Astrophysics, Cambridge.
H. H. Turner, Esq., D.Sc., D.C.L., F.R.S., Savilian Professor of Astronomy, Oxford.

Treasurer.

E. B. Knobel, Esq.

Secretaries.

A. S. Eddington, Esq., M.A., M.Sc., Plumian Professor of Astronomy, Cambridge.
Alfred Fowler, Esq., F.R.S.

Foreign Secretary.

Arthur Schuster, Esq., Sc.D., Ph.D., Sec. R.S.

Council.

Sydney Chapman, Esq., B.A., D.Sc.
Sir W. H. M. Christie, K.C.B., M.A., D.Sc., F.R.S.
Rev. A. L. Cortie, S.J.
A. C. D. Crommelin, Esq., B.A., D.Sc.
Walter Heath, Esq., M.A.
J. H. Jeans, Esq., M.A., F.R.S.
W. H. Maw, Esq., LL.D.
J. W. Nicholson, Esq., M.A., D.Sc., Professor of Mathematics, King's College.
Rev. T. E. R. Phillips, M.A.
A. A. Rambaut, Esq., M.D., D.Sc., F.R.S., Radcliffe Observer.
R. A. Sampson, Esq., M.A., D.Sc., F.R.S., Astronomer Royal for Scotland.
F. J. M. Stratton, Esq., M.A.